ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

VOL. XLIV. No. 9.

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THE U. S. BATTLESHIP "ALABAMA" had her contract trial trip on Aug. 28 off Cape Ann, and made an average speed of 17 knots over the entire course. The course was 33 miles in length; the run out was made in 1 hr. 55 min. 27 sec., or an average of 17.15 knots. The return was made in 1 hr. 57 min. 30 sec., or an average of 16.85 knots. The maximum number of revolutions was 118. The speed figures given above are subject to correction for the influence of tidal currents. The sea was smooth and the weather favorable. Five other battleships, the "Texas," "Massachusetts," "Indiana," "Kentucky," and "Kearsarge" were anchored to serve as stake boats to mark out the course. The "Alabama" was authorized by Congress, June 10, 1896, and she was launched at the Cramp shipyards on May 18, 1898. She was designed to make a speed of 16 knots.

THE STEAMER RECORD between New Orleans and New York has been broken by the new steamship "Proteus," of the Cromwell line. The time from South Pass to Sandy Hook, a distance of 1,490 miles, was 4 days 4 hours and 28 minutes. The best day's run was 442 knots.

THE NEW FRENCH STEAMER "LA LORRAINE," of the Compagnie Generale Transatlantique, which arrived on its first trip to New York last week, is said to be the largest steamship which has yet been built in France. Its dimensions are: Length, 580 ft. 8 ins.; beam, 60 ft. 2½ ins.; depth, 39 ft. 4 ins.; tonnage, 12,000 tons gross. The engines are of the four-cylinder triple-expansion type, calculated to develop 22,200 I. HP. The vessel is expected to maintain an average speed of 20 knots per hour. The best day's run on the first westward trip was 493 knots, or about 21 knots per hour. The vessel has accommodations for 378 first cabin, 118 second cabin and 953 steerage passengers.

A FLOATING DRY-DOCK is projected by the Risdon Iron Works, of San Francisco. It is intended to be the largest of its kind on the Pacific Coast. The company's plant is being put in shape to turn out ships of the largest size, and it promises to compete with the Union Iron Works for government work.

A STRONGLY FORTIFIED NAVAL BASE on the island of Guam is being planned by the navy department. Guam is 3,500 miles west of Honolulu and 1,600 miles east of Manila. A mixed commission of one army and two naval officers has been assigned to the work of the preliminary survey.

AN EXHIBITION OF IMPLEMENTS OF WAR is to be made a special feature at the Buffalo Exposition in 1901. Guns of the largest caliber are to be furnished by a prominent steel-producing firm. A firing ground will be established for heavy guns, the range to be over Lake Erie, and another firing ground for machine and automatic guns, the range being through a tunnel.

AN EXPOSITION OF FIRE-PREVENTING APPARATUS will be held in Berlin, Germany, during the summer of 1901. Those desiring to exhibit should address Mr. Emil Jacob, 41 Linden Strasse, Berlin, in regard to space and the conditions of competition. Steam, water and electric motive power will be supplied to the exhibitors. Measures are in progress to secure free entry to Germany for all exhibits coming from other countries.

A CONTRACT FOR ARMOR PLATE is reported to have been secured by the Carnegie Steel Co. from the Russian Government. The amount named is 1,000 tons, the price $560 per ton, and the plate is to be hardened by the Krupp process. The contract was secured through Mr. Millard Hunsiker, London agent of the Carnegie Co., and the material is to be delivered in Russia within 14 months. It is said that the armor will be used to replace compound English armor, which was applied 15 years ago to two Russian war vessels.

AN ORDER FOR 4,000 TONS OF STEEL RAILS has been placed by the Cape Government with the Carnegie Steel Co., of Pittsburg, Pa. This is the first order for rails that has been received in the United States from South Africa since the commencement of the war.

EXPORT COAL SHIPMENTS from Newport News in July aggregated 20,837 tons. A large amount of New River coal is to be shipped from that port to the Egyptian State railways. The movement of coal is hampered by the scarcity of freight vessels.

THE IRON ORE PRODUCTION of the United States for 1899 amounted to 24,683,173 long tons, according to a report made by Mr. John Birkinline for the U. S. Geological Survey. This is 5,249,997 tons, or 27% in excess of the previous maximum production, that of 1898. The nearest approach to these figures in any foreign country was that of England in 1880, 13,062,040 tons. The product of the Lake Superior region increased from 13,779,308 tons in 1898 to 17,802,955 tons in 1899. The product of the different ranges in that region in 1899 was: Marquette, 3,634,596; Menominee, 3,281,422; Gogebic, 2,725,648; Vermilion, 1,643,984; Mesabi, 6,517,305. The value of the total ore product at the mines was $34,999,077, averaging $1.42 per ton, an increase of 28 cts. per ton over 1898.

THE EXPORTS OF BUILDERS' tools and hardware, sewing machines, and typewriters from the United States in each fiscal year from 1890 to 1900, are shown in the following table. The exports of typewriters cannot be separately shown for the years prior to 1897, as prior to 1897 typewriters were published in the reports of the Treasury Bureau of Statistics under the general head, "Machinery," not elsewhere specified:

Fiscal year.	Builders' tools and hardware.	Sewing machines.	Typewriters.
1890	$3,851,397	$2,793,780	.....
1891	3,858,397	2,883,577	.....
1892	4,210,132	3,133,992	.....
1893	4,551,342	2,476,446	.....
1894	4,424,278	2,347,354	.....
1895	4,468,278	2,260,139	.....
1896	5,500,188	3,139,249	.....
1897	6,627,466	3,340,241	$1,453,117
1898	6,428,332	3,136,364	1,902,153
1899	7,842,372	3,264,344	2,449,205
1900	9,646,017	4,540,842	2,697,544

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred at Coshocton, O., Aug. 24, on the line of the Wheeling & Lake Erie Ry. A freight train ran into a washout, resulting in the death of the engineman and fireman.

THE ROGERS LOCOMOTIVE WORKS at Paterson, N. J., are to be closed permanently, according to reports, about the end of the year, and the property will be sold. Contracts now on hand will keep the works in operation till Dec. 1, but no more orders will be taken. Paterson at one time had three flourishing locomotive building establishments, the Grant, the Cooke and the Rogers. The Grant works, after years of inactivity, was moved to Chicago, and after an unsuccessful attempt at operation there was transformed to a manufactory of electrical machinery. The closing of the Rogers works will leave the Cooke plant the only one in operation in Paterson. The Rogers works has been in operation as an iron-working establishment since 1800; and locomotives have been built there since 1852. The recent death of the President of the company, Mr. Robert S. Hughes, and the desire of the principal stockholder, Mr. Jacob S. Rogers, to close out his interest are said to have brought about the decision to close the works.

INCREASE IN THE SIZE OF LOCOMOTIVES during the past half-dozen years is illustrated in the annual report of the Chicago & Eastern Illinois R. R. Co. just issued. It is there stated that the company in 1894 owned 138 locomotives of all classes, with an average total weight on drivers of 76,626 lbs. The company now owns 129 locomotives with an average weight on drivers of 108,964 lbs. In each year 80 locomotives were in freight-train service. The comparison of work done by freight locomotives in the two years is as follows:

	1894.	1900.
Revenue tons hauled one mile...	420,484,329	850,501,320
Revenue tons hauled per freight engine mile.	341.5	466.6

The enormous increase both in engine mileage and in train weights that has taken place, coincident with the increase in engine capacity, is a striking showing.

THE FREIGHT-CAR CAPACITY has been notably increased on the same road. In 1892 it had 9,249 freight cars of an average capacity of 23 tons. In 1900 it has but 8,259 cars, with an average capacity of 26⅘ tons, and it has recently ordered 500 new cars of 80,000 lbs. capacity each.

THE 3,000,000-BUSHEL GRAIN-STORAGE PLANT to be erected at Montreal by W. J. Conners, of Buffalo and associates is likely to be soon put under construction. An official statement regarding it was made by Hon. Robert Mackay, President of the Harbor Commissioners of Montreal on July 24, and is printed in the Annual Report of that body, just issued. According to this statement, the contract between the Harbor Commissioners and Mr. Conners was signed Jan. 9, 1900, and the latter party deposited $50,000 as a guarantee of good faith. Plans and specifications for a grain elevator and freight warehouse to be erected at Windmill Point were submitted in April and May and the necessary formal approval was given to the last of the plans on June 18. It is further stated that Mr. Conners and his associates have asked bids from contractors for carrying out the work.

DEEPENING THE GRASSE RIVER in Northern New York to secure a depth of 21 ft. of water is a project which has recently been investigated by Capt. Graham D. Fitch, U. S. Engineers. The company which is developing the water power at Massena desires the improvement, as it would give water transportation from the site of their power house to the St. Lawrence and thence to Montreal. A distance of about seven miles would require improvement.

WATER-POWER DEVELOPMENT at Sault Ste. Marie is making rapid progress. One canal of 20,000-HP. capacity is in operation, and a second, which will give 50,000 HP., is nearly completed. A third canal, with 40,000-HP. capacity, has just been started on the Canadian side of the river. The total expenditure to date on the various power development enterprises at this point is said to aggregate $4,500,000.

A LARGE WATER-POWER ENTERPRISE is under way at Hamilton, Ont. A canal is to be run from Lake Erie to Hamilton, and construction has begun at Silverdale, Ont., on the line of the canal. The source of the water supply is the Welland River, a stream which flows into the Niagara River. The canal will run to Jordan River, a stream which enters Lake Ontario. The total fall which can be utilized for power is about 250 ft. A contract to deliver 15,000 electric horse-power has been made with the Canadian Steel Co., located at Welland, which is expected to be in operation at about the same time as the power plant, in September, 1901. The canal is to be 150 ft. wide at the top, 60 ft. at the bottom, and 12 ft. deep, with a current of 3½ miles per hour. The initial plant is to develop 25,000 HP., which can be increased to 50,000 or 60,000, as required.

OIL FUEL FOR STEAM BOILERS has been abandoned by the Chicago Union Steam Traction Co. and coal substituted, for economical reasons. The Western Avenue and the Hobble Street electric power houses and the Rockwell Street cable stations are also preparing to substitute coal for oil.

TESTS OF BRICK PAVING BLOCKS made recently at Middletown, O., by Mr. Frank Doty, C. E., showed remarkably low absorption by some of the brands. In making the test, the bricks were immersed in water for three days and their increase of weight was then measured. The "Kentucky" brick absorbed only 0.23%, the "Union Paver" only 0.37%, and the "Logan" only 0.49%.

AN OPPORTUNITY FOR CEMENT MANUFACTURE exists in Porto Rico. The government is using cement there at present at the rate of 30,000 barrels a year and there is every indication of the existence of suitable raw materials for the manufacture on the island. This, with the cheapness of labor, makes the prospect for profit a promising one.

THE EAST BOSTON TUNNEL is now under construction by the Boston Transit Commission, work on section B, which is 4,330 ft. in length and includes the portion under the waters of Boston Harbor, having been begun on Aug. 13, sinking a shaft in Lewis St., East Boston. The tunnel will be driven with a hydraulic shield. Section A of the work, located in East Boston, is being built in open cut and concreting is in progress.

EXPERIMENTAL TEST OF A CONCRETE AND EXPANDED METAL CONDUIT FOR THE JERSEY CITY WATER SUPPLY.

By. R. Godfrey.*

The future water supply for Jersey City, from the storage reservoir at Boonton, N. J., now under construction by the Jersey City Water Supply Co., will be conveyed by means of conduits, tunnels and steel pipe.

For the conduit a section with brick arches was originally proposed, and then modified to Fig. 1, with concrete and expanded metal arch. A test

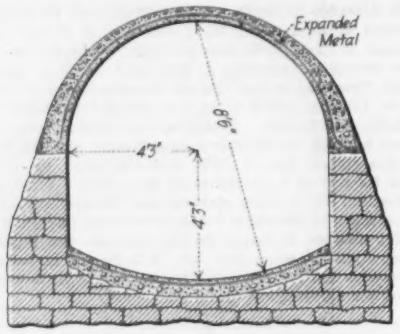

Fig. 1.—Experimental Test Section No. 1, Concrete and Expanded Metal Conduit, Jersey City Water Supply.

section of the latter was made on May 11, and after two weeks was loaded, as shown by the view, Fig. 2, with 13 tons of steel rails, to ascertain whether it was strong enough for the purposes of the conduit; the arch showed neither cracks nor any measurable deflection.

Subsequently it was thought to be desirable to construct a conduit section entirely of concrete and expanded metal, the New York Expanded Metal Co. offering to build and test a test section at their expense on the grounds of the Jersey City Water Supply Co.. In consequence, the writer designed the section, Fig. 3, practically half an ellipse, with the haunches and bottom forming an inverted arch. This section is an adaptation of similar sections constructed in Germany in the Monier system to expanded metal and the required conduit capacity. A test section thereof was constructed on June 8, over a collapsible centering.

The material used was 1½-in. to 1-in. crushed stone screenings of the same stone and sharp pit sand. The proportions of the sand and fine screenings to the coarser screenings and broken stone were approximately 1 to 2; the cement used was of the "Nazareth" brand.

The foundation up to the springing line d-d, Fig. 3, contained 7.2 cu. yds. of sand, screenings and stone, and 1.28 cu. yds. of cement, or approximately 1 part of cement, 2 parts sand and fine screenings and 4 parts coarse screenings and broken stone.

The upper part, above the springing line d-d, consisted of 4.8 cu. yds. sand, screenings and broken stone, and 0.65 cu. yds. of cement, or approximately 1 part cement, 2.5 parts sand and fine screenings, and 5 parts coarse screenings and broken stone.

The total cubical contents of the conduit section were 10.3 cu. yds., the total amount of material

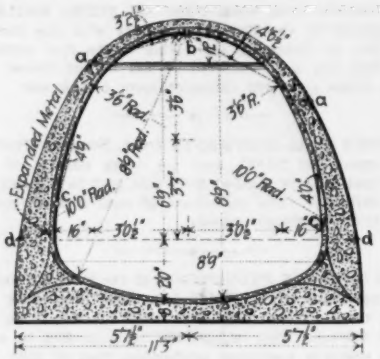

Fig. 3.—Experimental Test Section No. 2, Concrete and Expanded Metal Conduit, Jersey City Water Supply.

used, 12 cu. yds. sand, screenings and broken stone and 1.93 cu. yds. of cement, making a total of 13.93 cu. yds.

During the construction, when the lower part up to the spring line was completed, a heavy thunderstorm set in, and the rain washed part of the cement into the bottom of the section, and a small amount of ready concrete was lost on the platform. After the subsiding of the rain, the section was completed on the same day and was exposed to the sun rays up to date of test. The centering was removed on June 15, and the section was tested on June 29.

Three saddles of timber had been set on the crown of the arch, shown in Fig. 4, one in the center and one on each end, and one layer of nine rails had been laid on these saddles. The actual test began at 2.45 p. m., laying rails on, one by one, while a level had been set up to determine any deflection. At 5.28 p. m., with a load of 21½ tons, fine horizontal cracks began to show all along the extrado at the points marked a on Fig. 3, but no measurable deflection took place.

When the load had been increased to 25 tons, as shown in Fig. 5, three rails, weighing approximately one ton, were twice dropped on the rails on top of the arch over one end of the latter. The cracks, a, were slightly widened and new fine cracks showed at the intrado at point b and at the haunches at the p[illegible] running all along inside the conduit section [illegible] the rails were being dropped, the level ha[illegible] removed to avoid damage to the same.

The clear height of the section having [illegible]

Fig. 2.—View of Test Conduit No. 1, Loaded with 13 Tons of Steel Rails.

measured directly before the beginning of laying on rails, the same was measured over again 24 hours after completion of the test, and the total deflection at the crown of the arch was 7-16 in., and has not increased since (to July 16) under the constant load.

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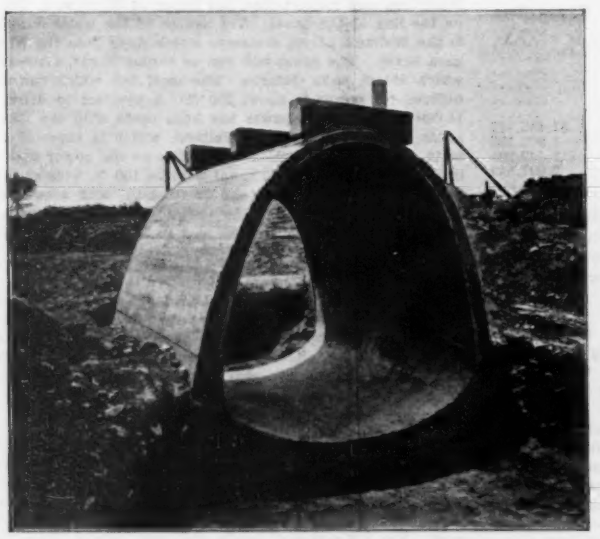

FIG. 4.—VIEW OF TEST CONDUIT NO. 2, READY FOR LOADING WITH RAILS.

FIG. 5.—TEST CONDUIT NO. 2, LOADED WITH 25 TONS OF RAILS.

STANDARDS OF TRACK CONSTRUCTION ON AMERICAN RAILWAYS.

The three tables which we publish herewith, showing the standards of track construction throughout the United States, Canada and Mexico, indicate pretty clearly the present character of construction as adopted and now in force for new work and renewals, although, of course, a considerable amount of lighter material and equipment exists on all these railways, and more particularly on their branches and inferior lines. The tables are compiled from special returns furnished by the chief engineers of the several railways, to whom we are indebted for the completeness of the information we are enabled to present. These tables represent an aggregate of nearly 120,000 miles of line in North America, and 3,350 miles in Mexico. The list comprises 47 of the principal lines in all parts of the United States, the two great railway systems of Canada, and three railways in Mexico. In another column we have discussed some of the important features in track work which are indicated by this compilation of recent information, and we give below some additional notes which could not well be included in the tables. In our issue of June 25, 1896, we gave similar tables, but on a less extensive scale than those which we now present.

TABLE I.—STANDARD RAILS, FASTENINGS, AND JOINTS.

	RAILWAY.	Rail.			Spike.		Rail Joints.													
									Angle Bars.		Bolts.		Spacing of Bolts.					Nuts.	Nut Locks.	Patented or Special Joints used.
		Wt. per yard.	Length.	Section.	Style.	Size.	Type.	Square or Broken.	Length.	Wt. per pair.	No.	Size.								
		lbs.	ft.			ins.			ins.	lbs.		ins.	ins.	ins.	ins.	ins.	ins.			
1	Atch., Top. & S. F.	65 and 75	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	22-in.-susp.	Broken	22	40 & 67	4	4½x⅝	..	5	5	5	..	Square	None	A few experimental	1
2	Balt. & Ohio	85	33	A. S. C. E.	Chisel pt.	6 x⅞	38-in.-3-tie Susp.	Broken Broken	38 24	48 & 81	6 4	4½x¾ 3¾x⅝	5	5	5	5	5	Square Square	None None	Continuous	2
3	Boston & Albany	95	30	Dudley	Goldie	5½x⅞	Supp.	Broken	20	43.72	4	4½x⅝	....	4¾	4¾	4¾	.....	Square	Excelsior	None	3
4	Boston & Maine	85	33	A. S. C. E.	Goldie	5$\frac{1}{16}$x$\frac{7}{16}$	Bridge	Square	24	.....	4	5⅝x¾	....	6	6$\frac{1}{16}$	6	.....	Hexagon	Excelsior on Weber, none on contin.	Weber and Continuous	4
5	Buff., Roch. & Pitts	100	33	A. S. C. E.	Goldie	5½x$\frac{5}{16}$	3-tie	Broken	42	109	6	4¾x⅞	7	7	7	7	7	Square	None (Harvey grip. th. bolts)	None	5
6	Burl. & Mo. River	75	30	A. S. C. E.	Chisel pt.	5½x$\frac{5}{16}$	3-tie	Broken	38	63	6	4 x⅞	5	5	5	5	5	Hexagon	Verona	None	6
7	Burl., C. R. & No.	80	30	A. S. C. E.	Chisel pt.	5½x$\frac{7}{16}$	Susp.	Broken	24	45 L-bar 58 Cont.	4	4⅜x⅞	....	6	6	6	.....	Hexagon	National and Verona Tail	Continuous	7
8	Canadian Pacific	80 & 100	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Square	26	76	4	4½x⅞	....	6½	5⅝	6½	.....	Square	Various	Bonzano is standard	8
9	Central of N. J.	80	30	Dudley	Goldie	5½x$\frac{5}{16}$	Susp.	Broken	30	60	6	4¾x⅞	5	5	4	5	5	Square	Verona	Continuous	9
10	Ches. & Ohio (Eastern Div.)	75	30	Special	Ord. & Ch. pt.	5½x$\frac{5}{16}$	Susp.	Broken	34	58	6	3⅞x¾	6	5	4	5	6	Square	None	Continuous	10
11	Ches. & Ohio (Western Div.)	100	30, 60	A. S. C. E.	Ordinary	5½x$\frac{7}{16}$	Susp.	Broken	34	88	6	4½x⅞	6	5	4	5	6	Square	None	None	11
12	Chic. & Northwestern	90	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Bridge	S. on tan. B. on cur.	26	48.8	4	3⅛x⅞	....	6	6	6	....	Square	.....	None in gen. use	12
13	Chic., Burl. & Quincy	75	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Supp.	Broken	38	68.75	6	4 x⅞	5	5	5	5	5	Square	Verona	None	13
14	Chic. Gt. Western	75	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Square	26	44.94	4	4¼x⅞	....	6	6	6	.....	Square	None	None	14
15	Chic., Ind. & Louisv	75	33	A. S. C. E.	Chisel pt.	5½x$\frac{5}{16}$	Susp.	Broken	24	50	4	4 x⅞	....	5	8	5	.....	Square	Verona	None	15
16	Chic., Mil. & St. P.	85	30	A. S. C. E.	Ordinary	5½x$\frac{7}{16}$	Supp.	Both	40	70	6	4¼x⅞	6	6	7	6	6	Hexagon	Verona	Continuous	16
17	Chic., R. Id. & Pacific	80	30	A. S. C. E.	Chisel pt.	5½x$\frac{7}{16}$	Susp.	Broken	24	59	4	4 x⅞	6	6	6	6	6	Square	Ver. tail	Continuous	17
18	Cin., N. O. & T. P.	75	30	Special	Ordinary	6 x⅝	Susp.	Broken	29, 30	51	6	4 x⅝	4⅜	4¾	4$\frac{1}{16}$	4⅜	4¾	Hexagon Square	Harvey Verona	Weber and Continuous	18
19	C., C., C. & St. L.	80	33	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	30	62	6	4½x⅞	6	5	4	5	6	Square	Nat. and Ver.	Few experimental	19
20	Del., Lack. & West.	80	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	30	62	6	4 x⅞	4¾	4¾	4	4¾	4¾	Square	American	Continuous	20
21	Den. & Rio Grande	85	30	Special	Ordinary	5½x$\frac{5}{16}$	Susp.	Square	26	52.2	4	4⅝x⅞	....	6	6	6	.	Square	Verona	.....	21
22	Erie	90	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	30	66.3	6	4½x⅞	4¾	4¾	4	4¾	4¾	Square	Verona	None	22
23	Fitchburg	85	33	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Bridge	Broken	24	74	4	4 x¾	....	6	6	6	.....	Square	National	Continuous is standard	23
24	Grand Trunk	80	30	A. S. C. E.	Ordinary	6 x$\frac{5}{16}$	Susp.	Broken	24	43.62	4	4⅝x1	....	6	6	6	.....	Square	Verona	None	24
25	Great Northern	80	30	Special	Ordinary	...	Supp.	Both	36	62	6	3¾x¾	7	4½	4½	4½	7	Hexagon	None	.....	25
26	Ill. Central	85	30	A. S. C. E.	Chisel pt.	5½x$\frac{7}{16}$	Supp.	S. on tan. B. on cur.	40	78	6	4½x⅞	9	4½	4½	4½	9	Square	Verona	None	26
27	K. C., Ft. S. & Mem.	75	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	24	42.75	4	4 x¾	..	5	5	5	.....	Square	None	Web., Cont. & Sellers	27
28	K. C. Southern	60 75	30 30	Cambria A.S.C.E.	Ordinary	5½x$\frac{7}{16}$	Susp.	S. on tan. B. on cur.	26	37	4 4	3⅝x¾ 3⅞x⅞	....	5 6	5½ 6	5 6	.....	Square	Verona	Continuous	28
29	Lake Shore & Mich. So.	80	30	A. S. C. E.	Goldie	5½x⅝	Supp.	Broken	24	44.6	4	4¼x¾	....	5	6	5	..	Square	None	None	29
30	Lehigh Valley	90, 100 on mtn div	30	A. S. C. E.	Goldie	5½x¾	Susp.	Broken	28	58 & 74	6	4¾x⅞	4	4	4	4	4	Hexagon	National	None generally	30
31	Louisv. & Nashville	70, 80	33	A. S. C. E.	Ordinary	5 x⅞	Susp.	Broken	29	59	6	4⅝x⅞	6	4½	4⅜	4½	6	Square	Verona	Exper. only	31
32	Mich. Cen.	80	30	A. S. C. E.	Goldie	5½x$\frac{7}{16}$	Susp. & Base	Broken	25	48	4	¾	....	6	6	6	.....	Square	None	Torrey	32
33	Mo., Kan. & Tex.	66	30	Special	Ordinary	5½x$\frac{7}{16}$	Bridge	Broken	22	41.6	4	3⅝x¾	....	5	5	5	.....	Square	Ver. on old bits	Continuous	33
34	Nash., Chat. & St. Louis	80	30	A. S. C. E.	Chisel pt.	5½x$\frac{7}{16}$	Susp.	Broken	28	51.5	6	4⅜x⅞	5	4	4	4	5	1½-in. sq.	Verona	None	34
35	N. Y. Central	80	33	Dudley	Goldie	5½x$\frac{7}{16}$	3-tie	Broken	36	69	6	4⅛x¾	5.6	5.6	5.6	5.6	5.6	Square	None	Continuous	35
36	N. Y., N. H. & H.	74 78 100	30 30 30	Special Special Special	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	24	35 58	4 4	3¾x¾ 4¼x⅞	..	7	5	7	..	Square	National	Weber	36
37	Norf. & Western	85	30	A. S. C. E.	Ordinary	5½x$\frac{7}{16}$	Susp.	Broken	30	60.4	6	4¼x¾	5	5	5	5	5	Square	None	.....	37
38	Nor. Pacific	72	30	No. Pac.	Ordinary	5½x$\frac{5}{16}$	Susp.	S. on tan. B. on cur.	24	36	4	3⅝x$\frac{32}{37}$	..	6	6$\frac{1}{16}$	6	.....	Square	Ideal nut	Only experimental	38
39	Ohio Central	70	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Supp.	Broken	24	33	4	4 x¾	....	4	8	4	.....	Hexagon	Excelsior	None	39
40	Pennsylvania	70, 85, 100	30	P. R. R.	Ordinary	6 x⅝	Susp.	Broken	30, 34	(Note)	6	(Note)	6	5	4	5	6	Square	Nat. and Ver.	Exper. only	40
41	Penn. Lines (P., C. C. & St. L.)	85	30	A. S. C. E.	Ordinary	5½x$\frac{7}{16}$	Susp.	Broken	33	62	6	4¾x⅞	6	5	5	5	6	Hexagon	Verona	Trial only	41
42	" " (P., Ft. W. & C.)	85	30	A.S.C.E. P. R. R.	Chisel pt.	5½x$\frac{7}{16}$	Susp.	Broken	34	60	6	5½x⅞ 5½x1⅛	6	5	3⅛	5	6	Hexagon	Verona	Barschall, Fisher & Heath	42
43	Phila. & Reading	80 90	30 & 45	Special A.S.C.E.	Chisel pt.	5½x⅝	Susp.	Broken	30	52 55	6	4⅝x⅞	5	4	4	4	5	Square	Excelsior	None	43
44	Pitts., Bess. & L. E.	100	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	32	84	6	4¾x⅞	5	5	5	5	5	Hexagon	Ver. and Nat.	None	44
45	Plant	70	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	26	45½	6	4 x¾	4	4	4	4	4	Square	National	None adopted	45
46	Seaboard Air Line	68, 80	30	Special	Special	5½x$\frac{7}{16}$	Bridge	Broken	22	50 & 59	4	4 x¾	..	6	6	6	.....	Square	National	Continuous (standard) and Weber	46
47	Southern	80	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	26	52	4	4½x⅞	..	7	4	7	.....	Square	None	Continuous and Weber	47
48	Sou. Pac. (Atl. System)	75	30	Special	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	24	42	4	4 x¾	....	5½	5½	5½	.....	Sq. 1⅛-In.	Verona	Bonzano	48
49	" " (Pac. System)	75	30	Special	Ordinary	5½x$\frac{5}{16}$	Susp.	Broken	24	40	4	4 x¾	....	5½	5½	5½	.....	Square	Ver. and Am.	Web., Cont., Bonz.	49
50	Union Pacific	80, 90	30	A. S. C. E.	Ordinary	5½x$\frac{5}{16}$	Susp.	Square	Old 26 to 40 New 29	50 to 58 55¾ & 65	4 6	4½x⅞	....	6	6	6	....	Hexagon	Various	None	50
51	Wabash	80	30	A. S. C. E.	Ordinary	5½x$\frac{7}{16}$	Susp.	Broken	32	96	6	⅞	6	5	5	5	6	Square	Verona	None	51
52	Mex. Central	75	30	Special	Ordinary	6 x½	Susp.	Square	24	47.5	4	4¼x⅞	....	5	5	5	.....	Square	None	None	52
53	Mex. International	75	30	A. S. C. E.	Ordinary	5¼x$\frac{5}{16}$	Susp.	Broken	24	38	4	4 x¾	....	5½	5½	5½	.....	Square	National	None	53
54	Mex. Interoceanic	56	30	Special	English	5¾x$\frac{7}{16}$	Susp.	Broken	24	...	4	4 x½	...	5	8	5	....	Hexagon	National	None	54

Rails.

Central R. R. of New Jersey.—The Dudley 80-lb. rail is standard and is 5¼ ins. high, with a base 5 ins. wide.

Chesapeake & Ohio Ry.—Rails 60 ft. long are used in tunnels.

Kansas City Southern Ry.—The 60-lb. rail is the No. 527 section of the Cambria Iron Co. The 75-lb. rail is of the Am. Soc. C. E. section.

Lehigh Valley R. R.—The 100-lb. rails are used on mountain grades; 90-lb. rails are used elsewhere.

Louisville & Nashville R. R.—The rails are 80 lbs. per yd. for the most important lines, and 70 lbs. on the less important lines. Of the rails delivered, 10% are in short lengths of 24, 27 and 30 ft., the standard length being 33 ft.

Missouri, Kansas & Texas Ry.—The rail is of the No. 6,602 section of the Illinois Steel Co., and approximates very closely to the Am. Soc. C. E. section.

New York, New Haven & Hartford R. R.—Rails of 74, 78 and 100 lbs. per yd. are used.

Pennsylvania R. R.—The rails used are 70, 85 and 100 lbs. per yd., with a standard length of 30 ft., though some 60-ft. rails are used.

Southern Pacific Ry. (Pacific System).—The 75-lb. rail is 5 ins. high and 5 ins. wide, but is not of the Am. Soc. C. E. section.

Rail Fastenings.

Baltimore & Ohio R. R.—The spikes are 9-16-in. square, 6 ins. long over all.

Central R. R. of New Jersey.—The Goldie diamond-point spike is used.

Cincinnati, New Orleans & Texas Pacific Ry.—The spikes are ⅝-in. square, 6 ins. long over all.

Grand Trunk Ry.—The spikes used are 6 ins. long over all.

New York Central & Hudson River R. R.—Screw spikes are employed experimentally.

Northern Pacific Ry.—The spikes are 9-16 × 5½ ins., with wedge points 1¼ ins. long.

Rail Joints.

Atchison, Topeka & Santa Fe Ry.—The 22-in. splice bars for 65 and 75-lb. rails weigh 40 and 67 lbs. per pair respectively; while the 38-in. bars weigh 48 and 81 lbs. per pair for the same rails.

Boston & Maine R. R.—The Weber and Continuous rail joints are used; the former has bolts 5¾ ins. long, with Excelsior nutlocks; the latter has no nutlocks.

Burlington, Cedar Rapids & Northern Ry.—The Continuous joints weigh about 58 lbs., and the nuts are hexagonal, 1⅝ ins. short diameter, 1 in. thick.

Canadian Pacific Ry.—The Bonzano rail joint has been adopted as standard, and is already in use on 50 miles of 100-lb. rails.

Central R. R. of New Jersey.—The road is experimenting with 1,000 Continuous joints, having 26-in. splice bars and six bolts.

Chesapeake & Ohio Ry.—(Eastern Division.) The road is experimenting with two miles of the Continuous joint.—(Western Division). Where locknuts are used they are of the National pattern, but for the past three years the Harvey grip-thread bolt has been used, without nutlocks.

Chicago, Milwaukee & St. Paul Ry.—Some divisions are laid entirely with broken joints, others are laid entirely with square joints. The Continuous joint is being used, and gives good results so far.

Cincinnati, New Orleans & Texas Pacific Ry.—The bolts are ¾-in. diameter, 4 ins. long under the head for grip-thread bolts, and 4¼ ins. where the Verona nutlock is used. There are 5¾ miles laid with the Weber joint, and 19½ miles with the Continuous joint. Both are found to be excellent.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—The rail joints have the wide National and Verona tail nutlocks.

Fitchburg R. R.—The Continuous rail joint is the standard pattern.

Grand Trunk Ry.—Joint ties are 4½ ins. apart in the clear.

Kansas City, Fort Scott & Memphis Ry.—The Weber, Continuous and Sellers rail joints are used, and are all satisfactory, but the Weber is considered the best.

Nashville, Chattanooga & St. Louis Ry.—Nuts on the track bolts are 1⅛ ins. square, and the Verona nutlocks for ⅞-in. bolts are ⅛ × 3-16-in.

New York, New Haven & Hartford R. R.—The 74-lb. rails have bolts ¾ × 4⅛ ins., and their splice bars weigh 35 lbs. per pair.

Norfolk & Western R. R.—The weight of splice bars is 60.4 lbs. per pair when punched.

Northern Pacific Ry.—The nuts of the track bolts are 1⅜ ins. square, 15-16-in. thick.

Pennsylvania R. R.—The bolts for 70 and 85-lb. rails are 13-16 × 5 ins. under the head; those for the 100-lb. rails are 1 × 4½ ins. The weights of angle bars per pair are as follows: 34-in. bars for 70-lb. rails, 54 lbs per pair; for 85-lb. rails, 63 lbs.; for 100-lb. rails, 75 lbs.; 30-in. bars for 100-lb. rails, 112 lbs.

Pennsylvania Lines (Pittsburg, Fort Wayne & Chicago Ry.)—The Barschall, Fisher and Heath joints are in experimental use.

Pittsburg, Bessemer & Lake Erie R. R.—The nutlocks are of the Verona and National extra-wide patterns.

Seaboard Air Line.—The Continuous rail joint is the standard pattern.

Southern Pacific Ry.—(Atlantic System). The Bonzano rail joint is being tried, but has not been in use long enough for results to be given.—(Pacific System). The Weber, Continuous, Bonzano and other special forms of joints are being tried. The nutlocks used are the Verona tail and the American twisted, with lug.

Union Pacific Ry.—The old joints have splice bars 26 to 40 ins. long, with four bolts, 6 ins. c. to c., the bars weighing 50 to 58.8 lbs. per pair. This year it has been proposed to adopt 29-in. bars with six bolts, the center pair 5 ins. c. to c. and the others 4½ ins. c. to c. The weight would be 55.7 lbs. per pair for 80-lb. rails and 65.3 lbs. for 90-lb. rails.

Ties.

Atchison, Topeka & Santa Fe Ry.—Treated ties were put in service during renewals in 1899 as follows: New Mexico pine, 406,288; Texas hewed pine, 242,274; Texas sawed pine, 445,723; total, 1,094,285.

Boston & Maine R. R.—Ties are required to be not less than 6 ins. wide, or 8 ins. if squared.

Burlington & Missouri River Ry.—The use of treated ties has only just been begun, the company having built a burnetizing plant in 1899.

Burlington, Cedar Rapids & Northern Ry.—The average cost of ties delivered f. o. b. on the B., C. R. & N. Ry. tracks in 1899, was a little under 50 cts. each for oak, and a little under 40 cts. each for cedar.

Canadian Pacific Ry.—The life of tamarack, hemlock, spruce and Douglas fir ties is about 8 years; cedar ties wear out before they decay.

Central R. R. of New Jersey.—White oak and rock oak ties last about 10 years; yellow pine, 11 years in main track; chestnut, 9 years in main track and 12 in sidings.

Chesapeake & Ohio Ry.—(Eastern Division). The ties are obtained mainly from the Piedmont district of Virginia.—(Western Division). White oak ties are used almost exclusively, with minimum dimensions of 7 × 7 ins., 8½ ft. in length. The cost of first-class ties is 33 cts.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—Some cedar and hemlock ties are used on branches and sidings.

Erie Ry.—A few of the oak ties used are obtained in New York state.

Grand Trunk Ry.—The life of oak ties is about 7 years; Georgia yellow pine, 10; cedar (Quebec), 9; tamarack (Ontario), 4 years. The cost is about 40 cts. for oak, 48 cts. for pine, 28 cts. for cedar, and 23 cts. for tamarack. Joint ties are 4½ ins. apart in the clear.

Lake Shore & Michigan Southern Ry.—The life of ties is about as follows:—Oak, from West Virginia and Kentucky, 6 to 9 years; oak obtained along the line, 10 to 14; cedar from Michigan, 10 to 14; chestnut obtained along the line, 9 to 12 years.

Louisville & Nashville R. R.—White oak ties are used north of Birmingham, Ala., and yellow pine south of that point. Cypress is also used on the New Orleans Division. There are 16 ties to an 80-lb. rail 33 ft. long, and 18 to a 70-lb. 33-ft rail. Passing tracks, except on curves, have 14 ties to a 30-ft. rail.

New York Central R. R.—The number of ties per rail is 18 for heavy traffic and 16 for ordinary traffic.

Pennsylvania R. R.—Chestnut ties are used in yards.

Pennsylvania Lines West of Pittsburg.—(Pittsburg, Cincinnati, Chicago & St. Louis Ry.) Black walnut and honey locust ties are used, but are too few in number to furnish a record as to their life. Treated ties are used to a limited extent for trial; there are 75,000 in use, mostly of beech and red oak.—(Pittsburg, Fort Wayne & Chicago Ry.) Oak ties last 9.2 years; tamarack, 5; cedar, wild cherry, honey locust and black walnut, 8; hackberry, 4. There are 14 ties to a rail on tangents and 16 on curves.

Plant System.—Yellow pine ties last 6 years in Georgia, South Carolina and Alabama, 4 years in Florida. Black cypress ties last 10 to 12 years.

Southern Pacific Ry. (Pacific System).—The cost of ties varies from 20 cts. at mills in Oregon, to 40 cts. delivered on the wharf at Port Los Angeles, Cal. On Dec. 31, 1899, there were 2,691,092 treated ties in use.

Union Pacific Ry.—There are 17 ties to a rail on main track, and 15 on branches.

Mexican Central Ry.—The use of treated ties was commenced in 1899, and there are now a few thousand in service.

Mexican Interoceanic Ry. (3 ft. 6 ins. gage).—There are 162 miles laid with English steel ties, the life of which is said to be at least 30 years. There is also a trial lot of 25,000 jarrah ties from Australia, for which a life of 15 years is guaranteed. The cost of ties is as follows: Oak, 75 cts.; cedar, 72 cts.; tropical woods, 85 cts.; jarrah, $3; pine, 45 cts.; steel (price when purchased), $2.25; all these amounts represent Mexican currency.

Tie-Plates.

Atchison, Topeka & Santa Fe Ry.—The Wolhaupter tie-plates used are 7 7-16 × 4¼ ins. for 65-lb. rails, and 7 13-16 × 4¼ ins. for 75-lb. rails.

Boston & Maine R. R.—Tie-plates are generally used on cedar ties only; the Goldie claw tie-plate on curves, and the Glendon flanged tie-plate on tangents.

Canadian Pacific Ry.—Various tie-plates are on trial; being used on all ties for 25 miles, and on curves only for 100 miles.

Central R. R. of New Jersey.—The tie-plates weig[h] lbs. for the intermediate ties, and 6 lbs. for the joint t[ies].

Chicago, Indianapolis & Louisville Ry.—Tie-pla[tes] are used on alternate ties on curves of 4° or over, bu[t one] are used on tangents.

Denver & Rio Grande R. R.—The Servis tie-pla[tes] are 6 × 8 ins. under the angle bars at joints, and 4¼ × [8] ins. on the intermediate ties. They are used on all [ties] on curves of 3° or over.

Erie Ry.—The tie-plates for 90-lb. rails are 5 × [8] ins., and weigh 3.31 lbs. They are used on all bridge t[ies] on all joint ties on curves; on all pine ties on curv[es] and are so placed on oak ties on curves that there will [not] be more than two consecutive oak ties without plates.

Grand Trunk Ry.—Tie-plates are used only on [curves] and at switches, but are used on all ties at such pla[ces].

Louisville & Nashville R. R.—Tie-plates are ge[nerally] of the Goldie pattern, used on curves or at other [places] where necessary to prevent spreading of track or de-struction of ties. They are not used on tangents. The plates are placed on joint and intermediate ties.

New York Central R. R.—The tie-plates are 6 × [9] ins. and 5 × 8 ins.; 3-16 and 5-16-in. thick, according to con-ditions. Other sizes are also used. They are used on joint ties and on curves; also on every tie where soft ties are used.

New York, New Haven & Hartford R. R.—Tie-plates are ¼ × 5 × 8 ins. for 74 and 78-lb. rails; ¼ × 5 × 8½ ins. for 100-lb. rails; weight, 4 lbs.

Pennsylvania R. R.—Tie-plates for joint ties are 6 × 11 ins., weighing 120 ounces; those for intermediate ties are 6 × 9 ins., 96 ounces.

Pennsylvania Lines West of Pittsburg.—(Pittsburg, Cincinnati, Chicago & St. Louis Ry.) Tie plates are used on all ties on curves, and on tangents where the rails cut the ties.—(Pittsburg, Fort Wayne & Chicago Ry.) Tie-plates are used on curves, where the engines use sand on tangents, and under rail joints at road crossings.

Pittsburg, Bessemer & Lake Erie R. R.—The Goldie tie-plates are used, on curves only, being placed on every tie. Those for joint ties are 7 × 8½ ins.; for intermediate ties, 6 × 8½ ins.; thickness, ⅜-in.

Southern Pacific Ry.—(Atlantic System). The Servis, Wolhaupter, Glendon and Q. & W. tie-plates are in use. The Servis plates are 5 × 8 ins.; all others, 4¼ × 8 ins.—(Pacific System.) The tie-plates are of the Servis, Glendon, Wolhaupter and Q. & W. patterns; 5 × 8 ins. for joint ties, and 4¼ × 8 ins. for intermediate ties.

Union Pacific Ry.—The tie-plates are ¼-in. thick, and of various sizes: 4 × 7½ ins., 4¼ × 7½ ins., 5¾ × 7½ ins., 4¼ × 8 ins. and 5¾ × 8 ins. They are used on all soft-wood ties on the main line, and on curves of 3° and over on branches.

Mexican Central Ry.—The Wolhaupter and several obsolete forms of tie-plates are used; they are used at the joints, and on all ties on curves.

Mexican International Ry.—The Servis tie-plates are 5 × 8 ins. and 6 × 8 ins. for intermediate and joint ties. The Glendon tie-plates are 4¼ × 8 and 6 × 8 ins.

Ballast.

Burlington, Cedar Rapids & Northern Ry.—The ballast is principally gravel, with considerable broken stone, some burnt clay, and some cinders from locomotive fire-boxes.

Erie Ry.—The stone ballast is broken to a 2-in. ring and screened.

Norfolk & Western R. R.—The ballast is mainly lime-stone and slag, with gravel on 250 miles at the western end of the line.

Pennsylvania Lines West of Pittsburg.—(Pittsburg, Fort Wayne & Chicago Ry.)—Stone ballast is used on main track; gravel, slag and cinders in yards.

Frogs.

Baltimore & Ohio R. R.—The flangeway at frog guard rails is 1⅞ ins. for straight frogs.

Burlington, Cedar Rapids & Northen Ry.—Rigid frogs of the bolted, clamped and riveted patterns are used on branch lines and in yards.

Chesapeake & Ohio Ry. (Western Division).—The standard frog is of the bolted pattern, but has considerable riveting. No. 10 is the standard frog on main track, except at the ends of double-track sections, where No. 14 frogs are used. The flangeway at frog-guard rails is 2¼ ins., the gage of track being 4 ft. 9 ins.

Chicago, Indianapolis & Louisville Ry.—Spring frogs are used for main track, except on the outside of curves. Rigid frogs are used for yards.

Cincinnati, New Orleans & Texas Pacific Ry.—Spring rail frogs are used for main track, and rigid frogs for sidings.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—Spring rail frogs are used for main track; and rigid frogs for sidings. No. 10 is the ordinary frog for main track, but No. 18 is used at the ends of double track.

Fitchburg R. R.—Spring rail frogs are used on the main track except in a few places. The rigid frogs are of the keyed pattern.

Lake Shore & Michigan Southern Ry.—The standard frog for main track is No. 10, but the others used are Nos. 12, 14, 16 and 20. Frogs above No. 10 are anvil faced. Yard frogs are rigid.

Louisville & Nashville R. R.—The spring-rail frogs are

TABLE II.—TIES, TIE-PLATES AND BALLAST.

	RAILWAY	Ties: Wood and Where Obtained	Ties: Average Life	Ties: Size — Width	Ties: Size — Thickness	Ties: Size — Length	Ties: Cost	Ties: No. per 30-ft. Rail	Ties: Preservative Process	Ties: No. of Treated Ties in Use	Tie-Plates: Make	Tie-Plates: Size	Tie-Plates: Where Used	Ballast: Kinds Used	Ballast: Depth Under Ties	
			yrs.	ins.	ins.	ft.	cts.								ins.	
1	Atch., Top. & S. Fe	Oak (Mo.), Treat. pine (N. M.) Treat. s. l. pine (Tex.)	....	8	6	8	....	18	Wellhouse	3,939,849	Wolhaupter	7 11/16x4¼	Curves over 3°	Stone, gravel, slag, bt. clay, cinders	10	1
2	Balt. & Ohio	W. oak, ch. oak, wild cherry, h. loc, blk. wal., chest., w. ced.	....	8	7	8½	....	15	.....	.....	Servis, Goldie	.....	Joint ties	Stone	12	2
3	Boston & Albany	Hard pine (Ga.), chest. (Va. and Mass.)	....	7	7	8	50, 55	15	None	None	Servis, C. A. C. and Goldie claw	5⅜x 8⅜x¼ 6 x10½x¼	All ties on curv. Joints	Gravel	24	3
4	Boston & Maine	Cedar (Can.), chest. (B. & M.), yel. pine (Ga.)	....	6	6 to 8	8	Cedar, 30 Chest., 45	16	None	None	Goldie on curves Glendon on tan.	5x8	Cedar ties	Gravel	12	4
5	Buffalo, R. & P.	Oak (W. Va. and Pa.)	6 to 8	7	7	9½	60	16	None	None	Glendon	5x8	Joints and all curv. over 3°	Gravel, cinder and stone	12	5
6	Burl. & Mo. R	Pine, oak, cedar.	....	8	6	8	....	18	Chl. of Zinc	Few	Goldie and C. A. C.	5x7½x5/16	Curves over 1°	St., gr., bt. cl., sl., cin.	8	6
7	Burl., C. R. & N.	W., burr and post oak (Tenn.) W. cedar (Minn. and Mich.)	....	8	6	8	50 40	17	None	None	Various	.....	Curves mainly	Gravel, bt. clay, stone, cinders	10	7
8	Can. Pac.	Cedar, tamarac, spruce, hemlock and D. fir in B. C.	Note	8	6½	8	22	15 to 18	None	None	Various	.....	(Note)	Gravel, cinders	12	8
9	Central New Jersey	W. and rock oak, chest. (E. and cen. Pa., Va., W. Va.), Yell. pine (So. States.)	Note	9	7	O., 8 Y. P., 8½	68 62	16	Creosoting	88,656 m.t. 11,681 sid.	Goldie (Note)	Int. 6x7 x⅜ Jt. 7x7½x⅜	All ties	Stone, slag	8	9
10	Ches. & Ohio (E. Div.)	W., post, and chest. oak (Va.)	8	7	7	8½	....	16	None	None	Servis	5x7½; 42-oz.	Curves only	Stone	8 to 12	10
11	Ches. & Ohio (W. Div.)	W. oak (along line).	7 to 8	7	7	8½	33	15	None	None	Various	.....	.....	Stone, slag	6	11
12	Chicago & Northwestern	Oak (8 to 9 yrs.), cedar.	12 to 14	8	6	8	....	16	None	None	Glendon	5x8½	Bridges only	Stone and gravel	12	12
13	Chic., Burl. & Quincy	Oak (South).	10	8	6	8	....	18	None	None	.....	4½x8	Bridges and curv.	Grav. and bt. clay	8 min	13
14	Chic. Gt. Western	Oak, pine (Ark. and Mo.)	....	8 to 11	6 to 7	8	50	17	None	None	Servis	4¾x7¾	Soft ties only	Gravel and stone	8 min	14
15	Chic., Ind. & Louisville	W. burr. and chest. oak (So. Ind. and No. Ky.)	8	8	6	8	50	16	None	None	Wolhaupter	4¾x8; 2¾ lbs.	(Note)	Gravel and stone	6 to 10	15
16	Chic., Mil. & St. Paul	W. oak (So. 8 yrs.), (Wis. and Ia.) W. cedar. Hemlock and tamarac	10 15 5 to 6	8	6	8	....	17	None	None	Q. & W.	5x8x7/16	All soft ties	Gravel, stone, cinders and bt. gumbo	10 to 12	16
17	Chic., Rock Island & Pac.	Oak (Mo. and Ark.). Cedar (Mich. and Wis.)	7 15	8	6	8	45 53	17	Formerly burnetized hemlock	1,824,977 in m. t. and sid.	Wolhaupter and Glendon	4x8	Cedar ties	Gravel, stone, cinders and bt. clay	6	17
18	Cin., New O. & Tex. Pac	Oak (mtn. dists. along road).	7	9 to 12	7	8½	30	14	None	None	Serv., Gold., Oliver	7½x5x7/16	Brg. only; all ties	Stone, slag, gravel	12	18
19	Clev., Cin., Chic. & St. L	W. and post oak, chest., blk. wal., honey locust (along line and E. Ky.)	8 to 10	8	7	8	40 to 50	18 (33 ft.)	None	None	Goldie C. A. C.	6x7x¾ 6x8x⅜	Curves, switch., bridges, yards	Gravel and stone	12	19
20	Del., Lack. & Western	Oak, chest., pine, cedar, (Pa., N. J., N. C., S. C.)	O., 8 others 7	9	7	8½	55	16 to 17	None	None	Wolhaupter	4½x8x¾; 3 lbs.	Curves, all ties	Stone, scr. gravel, gravel and cinders	4 to 10	20
21	Denver & Rio Grande	Red spruce (along line)	9	7 to 11	6½ to 7½	8	40	19	None	None	Servis	6x8 jts.; 4¼x8 int.	(Note)	Stone and gravel	10	21
22	Erie	W., rk. and br. oak (Va., W. Va., N. Y.). Yell. pine (Ga., Fla.)	8 8	7 9	7 7	8½ 8½	60 to 70	16	None	None	Servis	5x9x7/16; 3.3 lbs.	(Note)	2-in. stone, gravel	12	22
23	Fitchburg	Chest. and oak (along line), Hard pine (So.)	7	6	6	8	38	16 tan. 17, 18 cur	None	None	Servis and Glendon	4½x8	Curves over 4°	Gravel	18	23
24	Grand Trunk	Oak (7), cedar (9), Yell. pine (10), tam. (4).	Note	8	6	8	40 and 28 48 and 23	18 to 19	None	None	Goldie	8x6x⅜	Curv. and switch.	Gravel and cinders	12	24
25	Great Northern	Various.	....	7	7	8	....	16	None	None	Gt. Nor.	5½x8x7/16; 3 lbs.	All ties	Gravel mainly	10 to 24	25
26	Illinois Central	Oak (So. of Ohio river), Cypress (So. of Ohio river).	5 to 9 5 to 9	8 9	6 7	8 9	....	18	None	None	Servis	5x8	Curves, switch, and cypress ties	Gravel and stone	10	26
27	Kan. Cy., Ft. S. & Mem	Oak (Mo. 8 yrs. Ark. 7 yrs.)	....	8	6	8	27	18	None	None	Goldie, Servis	Discontinued ex.	on bad curves	Stone and slag	12	27
28	Kan. Cy. Southern	W., post and burr oak. Long-leaf yell. pine.	....	8 9	6 7	8 9	26 28	18	None	None	Goldie	.....	Curves only	Stone, grav., cinders, sand	12 10	28
29	Lake Shore & Mich. So	Oak, cedar, chestnut (Note).	....	10	7	8¼	....	15	None	None	Various	5x8x¼	Soft ties and sw.	Gravel	12	29
30	Lehigh Valley	W. oak (native and So.), yell. pine (So.), cedar (Canada).	....	9	7	8 and 8½	50 to 70	16	None	.....	Goldie, Glendon	Jts. 6x9¼x5/16 Int. 5x9¼x5/16	Switch leads and sh. curves	Stone, gravel, slag and cinders	8	30
31	Louisville & Nashville	W. oak, yell. pine and cypress (along line)	....	9	7	8½	25 to 45	16 to 18 (33 ft.)	None	None	Goldie	⅜	(Note)	Stone, gravel, slag, cinders	12	31
32	Michigan Central	Cedar (life not known), oak.	8	8	6	8	50	16	None	None	Goldie, Servis, Wol., Glen., Q. & W.	.....	All cedar ties	Gravel	12	32
33	Mo., Kan. & Tex	Oak, cypress (Mo., In. Ter., Ark., Tex. and La.)	O., 8	8	6	8	40	17 to 18	None	None	(Various but only experiment)	.....	.....	Stone, bt. clay	6	33
34	Nash., Chat. & St. Louis	W. and post oak.	6 to 8	8	7	8½	30	16	None	None	None	.....	.....	Stone, gravel	12	34
35	N. Y. Central	Yell. pine (Ga., Fla., Ala.) W. oak (W. Va.) Oak and chest. (local), Cedar (Mich.)	9 9 8 12	9	6	8	50 to 60	16 and 18	Creosoting	10,000	Glendon, Wolhaupter	6x9 and 5x8	(Note)	Gravel, 2-in. stone	12	35
36	N. Y., N. H. & Hartford	Chest. and oak (along line).	5 to 7	8	6	8	40	16 and 18	None	None	Servis	(Note)	Brgs. and sw. lds.	Stone, 14-ins.; gravel	12	36
37	Norfolk & Western	W. oak (along line).	9	7	7	8½	30 to 40	16	None	None	Glendon	4¼x8½x¼	All ties on 5° curv	Stone, slag, gravel	10	37
38	Northern Pacific	Oak, fir, pine, tamarac.	5 to 7	....	7	8	25 to 50	17	None	None	Servis	5x8; 2.9 lbs.	Curves only	Gravel, stone, cinders	8	38
39	Ohio Central	Oak, mostly O. and W. Va.)	7	9	7	8½	42	14 to 16	None	None	Servis, Q. & W.	5x6¾	Curves only	Gravel, slag, stone	8	39
40	Pennsylvania	W. oak, yell. p. (Va. & along line)	8 to 10	10	7	8½	57	14	None	None	.....	6x9 and 6x11	All ties	Stone, gravel, cinders	8	40
41	Penna. Lines (P., C., C. & St. L.)	W., burr & chest. oak (O., W. Va., Ind., Ky.), h. loc., blk. wal.	....	8	7	8½	50 to 55	16	Trials only	75,000	Servis, Goldie	.....	Curves	Stone, gravel	10	41
42	" (P., Ft. W. & C.)	Oak cedar.	Note	8	7	8½	50	14 T.; 16 C.	None	None	Gold., Serv., Wol.	.....	Curves	Stone	10	42
43	Phila. & Reading	Oak, yell. pine, chestnut.	....	9	7	8½	O., 65; P., 48	16	None	None	None	.....		Stone, slag	8	43
44	Pitts., Bess. & L. E.	W. oak (W. Va. and local).	6 to 9	8	7	8½	50 to 62	14	None	None	Goldie claw	Int., 6x8½; Jt., 7x8½	All ties on curves	Slag	12	44
45	Plant	Yell. pine (Ga.) Black cypress.	4 to 6 10 to 12	9	7	9	P., 23; C., 25	16	None	None	None	.....	.....	Gravel and cinders	6	45
46	Seaboard Air Line	Oak and pine (along line).	7 and 6	9	7	8	P., 24; O., 33	16	.....	Few only	Servis	.....	.....	Gravel, stone, earth	..	46
47	Southern	Oak, pine, cypress.	Aver. 7	9	7	8½	O., 30 to 35 P., 23 to 25	16	None	None	Servis and others	5 ins. wide	Curves mainly	Stone, slag	4 to 8	47
48	So. Pac. (Atl. System)	Cypress (La.) Treat. yell. pine (Tex., La.)	6 7	10 8	7 6	9 8	34 28½	16	Chl. of Zinc (Burnet)	.....	Serv., Wol., Glen. and Q. & W.	(Note)	All ties	Gravel, stone	8	48
49	So. Pac. (Pac. System)	Rwood, sp., p. (Cal., Ore., Tex.)	....	8	7	8	20 to 40	16	Chl. of Zinc (B.)	2,691,092	Ser., Wol., Glen., Q. W.	(Note)	.....	Gravel, stone	8	49
50	Union Pacific	Pine (Wyo.) Fir (Ore.) Oak (Ark., Mo.)	6 8 9	8 8 8	8 7 6	8 8 8	....	17	None	None	Wol., Servis	(Note)	(Note)	Bt. clay, decom. granite, slag, cinders	7 to 9	50
51	Wabash	Oak (along line).	8	8	6	8	40	17	None	None	Servis and Wol.	5x9	On all ties	Gravel	10	51
52	Mex. Central	Various (Note)	....	8	6	8	....	16	.....	Few thous.	Wol., &c.	.....	(Note)	Various	10	52
53	Mex. International	L-leaf sawed pine (Tex.) Native hewed pine.	8 4	8	6 7	8 8	$1 Mex. 75c. Mex. (Note) 75	16 tan. 17, 20 cur	Burnetizing	437,000	Servis and Glendon	(Note)	All ties on curves	Gravel, stone	10	53
54	Mex. Interoceanic	Oak. Cedar. Pine (Mex.) Steel (English). Jarrah (Australia). Trop. woods (Mex.)	5 5 1½ to 2 30 15 5	8	6	6½	72 45 $2.25 2.00 85	16	None	None	None	.....	.....	Bt. clay (volcanic), River gravel, Volcanic ash	4	54

TABLE III.—FROGS, SWITCHES, ETC.

	RAILWAY.	Frogs.				Switches.		Curve guard rail.		
		Standard patterns.	Spring or rigid	Nos. for main track.	Nos. for yards.	Standard pattern.	Length of switch rail.	Flangeway.	Used on what curves.	
								ins.	degs.	
1	Atch. Top. & S. F.	Eureka	Spring	9	9, 6½	Channel split	ft.	...	...	1
2	Balt. & Ohio	Bolted	Spring	10	8, 7, 8	split	15	1⅝	...	2
3	Bost. & Alb.	Bolted	Rigid	8	8, 7, 8	split	18	1⅝	...	3
4	Bost. & Me.	Bolted	Rigid	10	6, 7, 8	split	15	1⅝	...	4
5	Buff., Roch. & Pitts.	Riveted	Spring	9	6, 7, 8	split	18	1⅝	14° curve, sid. only	5
6	Burl., C. R. & Nor.	...	Spring	11	9 stiff	split	15	1⅝ +	17	6
7	Burl., Ia. Fls. & So. Mo.	...	Spring	9	7	split	15	1⅝ tan.	None used	7
8	Can. Pacific	Plate, clamped	Rigid	9	7	Stub and Split	18	1⅝	...	8
9	Central of N. J.	Various	Rigid	10, 12, 15	6, 7, 8, 10	split	20	2⅜	Bridges only	9
10	Ches. & Ohio (E. Div.)	Bolted	Both	10 spring	7 rigid	split	15	2⅜	None used	10
11	Ches. & Ohio (W. Div.)	Bolted	Spring	10, 14	7, 8	split	15	2⅜	...	11
12	Chic. & No. West.	Bolted	Spring	10, 14	7, 8	split	15	1⅜	6°	12
13	Chic., Burl. & Q.	Bolted	Both	9, 11, 15	6, 7, 9	split	15, 24	1⅝	None used	13
14	Chic. Gt. West.	...	Spring	9	6, 7, 9	split	15	1⅝	None used	14
15	Chic., Ind. & Louisv.	Bolted	Spring	10	7	split	15	1⅝	15	15
16	Chic., Mil. & St. P.	Bolted	Spring	10	7	split	15	1⅝	10	16
17	Chic., R. Id. & Pac.	Plate, riveted	Spring	10	7	split	15	2⅜	25	17
18	Cin., N. O. & T. Pac.	Riveted	Spring	9	7	split	18	2⅜	(Note)	18
19	C., C., C. & St. L.	Bolted	Both	10, 18	7, 8, 9	Sp. & Wharton	18, 30	2⅜	16 and over	19
20	Del., Lack. & West.	Plate	Spring	8, 10	6, 7, 8	Sp. & Wharton	15	1⅝	None used	20
21	Den. & Rio Grande	Bolted	Rigid	8½, 10	7, 8½	split	15	1⅝	None	21
22	Erie	Bolted	Spring	10	7, 8½	split	18	2	(Note)	22
23	Fitchburg	(Note)	Spring	9	5, 6½, 7, 8	split	15	1⅝	None	23
24	Grand Trunk	Eureka	Spring	10	7	split	15	1⅝	None	24
25	Great Nor.	Bolted	Both	9	7	split and Stub	15	2	None	25
26	Ill. Central	Riveted	Both	10	7, 9	split	15	1⅝	None	26
27	K. C., Ft. S. & Mem.	...	...	9	7	split	15	1⅝	None	27
28	K. C. Southern	Clamped	Spring	9	6, 8, 10	split	15	1⅝	None	28
29	Lake Sh. & Mich. So.	Bolted	Spring	10	8, 10, 12	split	10, 12, 15	1⅝	None	29
30	Lehigh Valley	Filled and bolted	Both	8, 10, 12	6, 7, 8, 10	split	15, 21	1⅝	None	30
31	Louisv. & Nash.	Plate and clamped	Spring	9½	7	split	15	1⅝	Lim. extent	31
32	Mich. Cent.	Bolted	Both	11	9	split	15	2¼	None	32
33	Mo., Kan. & Tex.	Eureka	Spring	9	7, 9	split	15	2¼	16° and over	33
34	Nash., Chatt. & St. L.	Plate, riveted	Spring	9	6, 9	split	15	1⅝ & 2	None	34
35	N. Y. Central	Bolted	Both	10 spring	7 rigid	split	15	1⅝	16° and over, turnouts	35
36	N. Y., N. H. & H.	Bolted	Both	10, 15	7, 8	split	15, 24	1⅝	12°	36
37	Nor. & West.	Riveted plate	Spring	9	7	split	15	1⅝	In some cases	37
38	Nor. Pacific	Clamped	Spring	9	7	split	15	1⅝	14° (only one)	38
39	Ohio Central	...	Spring	9	7	split	15	1⅝	9° and over	39
40	Pennsylvania	Various	Both	8 to 24	4, 6	split	10, 18, 24, 30	3	No standard	40
41	Pa. Lines (P., C. C. & St. L.)	Clamp, bolt., key	Spring	10, 12, 15	6, 7, 8	split	15, 18	1¾ & 2	20° and over	41
42	" (P., Ft. W. & C.)	Bolt., key and riv.	Both	10	7, 8	Sp. & Wharton	18, m.t.	2	...	42
43	Phila. & Read.	...	Both	10	7, 8	split	15, yds.	1¾	...	43
44	Pitts., Bess. & L. E.	Filled and bolted	Spring	10, 12, 15	6, 8, 8	split	20, 28	1⅝	None	44
45	Plant.	Bolted	Both	10	7, 8	split	18	2	None	45
46	Seaboard A. L.	...	Spring	9	8	Wharton, m. t.	15	1¾	20° and over	46
47	Southern	Riveted	Spring	10	7	split, yds.	...	1⅝	Few only	47
48	Sou. Pac. (Atl. System)	Eureka	Spring	9	7, 8	split	15	2½	20°	48
49	Sou. Pac. (Pac. System)	Keyed	Spring	9	7, 7½	split	15	1⅝	14°	49
50	Union Pacific	Bolted	Spring	10	7, 8½	split	15	1⅝	...	50
51	Wabash	Plate	Spring	9	7, 8	split	15	2	...	51
52	Mex. Central	Clamp. and bolt.	Rigid	9	6½, 9	Wharton	15	1⅝	20° and over	52
53	Mex. International	Keyed	Both	9	6 to 9	split	15	1⅝	8°	53
54	Mex. Interoceanic	Riv. and bolt.	Rigid	8, 10	8, 10	split	12	1⅝	None	54

a combination of clamps and plates riveted to the frog. Rigid frogs are of the clamped pattern.

Nashville, Chattanooga & St. Louis Ry.—The flangeway at frog guard-rails is 1⅝ ins. for a gage of 4 ft. 8½ ins., and 2 ins. for a gage of 4 ft. 9 ins.

Norfolk & Western R. R.—The frogs are riveted ¾-in. plates, spring-rail frogs on plates being used on the main line and rigid plate frogs for yards. The standard frog for main line is No. 9, with Nos. 8, 10 and 12 as exceptions. The standard for yards is No. 7, with Nos. 6 and 8 as exceptions.

Northern Pacific Ry.—Rigid frogs are used in yards.

Pennsylvania R. R.—Clamped, bolted, keyed and plate frogs are used.

Southern Pacific Ry. (Atlantic System).—No. 7 is the standard frog for yards, but Nos. 5 and 6 are used where necessary.

Mexican Interoceanic Ry.—The frogs have riveted plates, with cast-steel fillers bolted through the rails.

Switches.

Baltimore & Ohio Ry.—Switch rails are 18 ft. long for main track and 15 ft. for sidings.

Burlington & Missouri River R. R.—The standard switch is the Clark-Jeffery split switch.

Canadian Pacific Ry.—The old standard switch was of the stub pattern. Split switches are used with 100-lb. rails, and the McPherson switch is used with some of the new rails.

Cincinnati, New Orleans & Texas Pacific Ry.—A few Wharton switches are in use. There is no spring in the switch rod.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—The ordinary switch rails are 18 ft. long, but those at the ends of double track are 30 ft. long.

Norfolk & Western R. R.—The standard length of switch rail is 15 ft., but many 18 ft. in length are in use.

Pennsylvania Lines (Pittsburg, Fort Wayne & Chicago Ry.)—The standard length of switch rail is 18 ft. for main track and 15 ft. for yards.

Plant System.—The Wharton switch is used in main track, and the split switch in yards.

Switchstands.

Boston & Maine R. R.—The Ramapo automatic switch-stand is the standard pattern.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—The switchstands are automatic when not locked for the main track, and there is no spring in the switch rod.

Delaware, Lackawanna & Western R. R.—Automatic and rigid switchstands are used; rigid for facing points.

Erie Ry.—Switchstands are automatic when not locked, but are locked so as to be rigid when the switch is set for the main track. No spring is used in the switch rod.

Pennsylvania Lines (Pittsburg, Cincinnati, Chicago & St. Louis Ry.)—A low automatic switchstand is used, locked when set for the main line. There is no spring in the switch rod.

Pittsburg, Bessemer & Lake Erie R. R.—The Ramapo safety switchstand is used, with an adjustable crank.

Southern Ry.—The standard switchstand is the "New Century," made by the Pennsylvania Steel Co.

Turnouts and Distant Signals.

Baltimore & Ohio R. R.—On double track, facing points are protected by distant signals.

Chesapeake & Ohio Ry. (Eastern Division).—Main line turnouts are protected by distant signals where the switch tangent cannot be seen by approaching trains.—(Western Division.) There is no standard for turnouts from double track.

Delaware, Lackawanna & Western R. R.—The Johnson semaphore signal is used for the protection of important turnouts.

Erie Ry.—Turnouts are only protected by distant signals when controlled by interlocking plants.

Michigan Central R. R.—Main line turnouts are protected by distant signals when the view is obstructed, and within the limits of the automatic block system.

Pennsylvania Lines (Pittsburg, Cincinnati, Chicago & St. Louis Ry.)—All main-line turnouts are protected by distant signals when on curves, or when the view is obstructed.

Pittsburg, Bessemer & Lake Erie Ry.—The sharpest turnout in main track has a No. 5 frog, but this is only used by switch engines.

Southern Pacific Ry. (Pacific System).—Facing switches are protected by distant signals when the view of the target is obscured.

Mexican International Ry.—The sharpest turnout in main track is 6° 05′ (25 meter chords); 7° 30′ (100-ft. chords).

Footguards.

Cincinnati, New Orleans & Texas Pacific Ry.—The footguards for frogs, guard rails, etc., are plank fillers, except in Ohio, where the National spring footguard is used.

Cleveland, Cincinnati, Chicago & St. Louis Ry.—The footguards for frogs and guard rails consist of wooden blocks or bent steel plates, and sometimes gravel and cinder filling.

New York Central R. R.—A special steel filler acts as a footguard in frogs. Wooden blocking is used elsewhere.

Norfolk & Western R. R.—Wooden blocks are generally

used as footguards for frogs and switches, but several forms of iron switchguard are being tried.

Ohio Central Ry.—Wooden footguards are used at frogs and switches, but iron guards are being arranged for.

Pennsylvania Lines (Pittsburg, Cincinnati, Chicago & St. Louis Ry.)—The footguards for frogs, guard rails, etc., are of the pattern made by the Cleveland Frog & Switch Co.

Pittsburg, Bessemer & Lake Erie R. R.—The Sheffield metal footguard is used in Ohio, and wooden blocking in Pennsylvania.

Guard Rails on Curves.

Boston & Albany R. R.—Curve guard rails are not used on main line, but on curves of 14° and over on sidings.

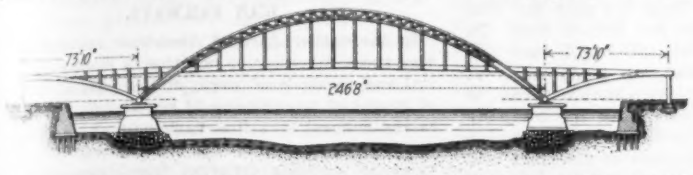

FIG. 1.—DIAGRAM ELEVATION OF FOOT BRIDGE OVER THE RIVER SEINE, BETWEEN THE ALMA AND JENA BRIDGES, PARIS.

Boston & Maine R. R.—The flangeway at guard rails, on curves is 1¾ ins., plus the amount of the widening of gage.

Burlington & Missouri River R. R.—The flangeway at curve guard rails is as follows: 1¾ ins. on tangents, 2 ins. on 5° to 9° curves, 2¼ ins. on 10° to 14° curves, 2½ ins. on 15° to 19° curves, 2¼ ins. on 20° curves.

Burlington, Cedar Rapids & Northern Ry.—There are very few curves with guard rails, and none of these are on the main line. In some yards they are used on 18° curves, being placed generally 5 ins. inside of the outer rail.

Chesapeake & Ohio Ry. (Western Division.)—Except around large cities, curves sharper than 20° are not introduced. Guard rails on curves are not used to any extent.

Chicago, Indianapolis & Louisville Ry.—No curve guard rails are used on main track, but in yards they are used on curves of 15° or more.

Cincinnati, New Orleans & Texas Pacific Ry.—Curve guard rails are used only in two dangerous places with 6° curves. Guard rails are also used on bridges, extending three rail lengths beyond the ends of the bridges.

Erie Ry.—Curve guard rails are used only on a few sidings; generally on curves of 20° or over where yard engines are used, and on curves of 16° or over where road engines are used.

Lake Shore & Michigan Southern Ry.—There are no main-line curves sharper than 6°.

New York Central R. R.—There are no main-track curves requiring guard rails.

Southern Pacific Ry. (Atlantic System.)—Curve guard rails are used only on sharp curves in tracks to industrial plants.

Mexican Central Ry.—Guard rails are used on curves of about 20° (100-ft. chords), and all curves sharper than this.

STEEL ARCH FOOT-BRIDGE OVER THE SEINE AT PARIS.

Among the problems presented by the location of the Paris Exposition of 1900 on the two banks of the Seine, was that of permitting a free circulation of visitors across this river without congesting travel on the great bridges of Alexander II. and Jena. To meet the conditions imposed

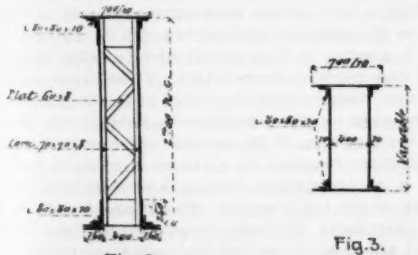

Fig. 2. Main Arch. Fig. 3. Portal Arch.

Figs. 2 and 3.—Sections of Main and Portal Arches of Foot Bridge Over the River Seine, Paris.

foot-bridges were built. One of the most interesting of these structures is located between the bridges of Alma and Jena, and is illustrated in the accompanying cuts.

This bridge has a total length of 393.6 ft., including a central span of 246 ft. and two side spans of 73.8 ft. (Fig. 1). The width between arch centers is 29.5 ft., and between the hand railings is 25.24 ft. The floor of the bridge is suspended from the central arch, which is hinged at the springing line; the two end semi-arches formed the counterpoise during the erection of the bridge on the cantilever principle. The piers supporting the center span are built of masonry, and the anchorage at the ends of the shore spans is also masonry, with the end posts hinged at both ends.

The central arch, in section, is a solid riveted box, from the spring to the floor level (Fig. 2); and above this level there are separate framed top and bottom chords connected by posts and diagonals (Fig. 3). The side arches are the same in construction as the lower part of the main arch. The floor system is made of two longitudinal I-beams, made of plates and angles, and spaced 26.2 ft. apart, and on these rest the cross-beams and the floor planking (Fig. 4). The hinged arch support (Fig. 5), is steel, with a pin 10.4 ins. diameter and 3.38 ft. long; each steel shoe on the ends of the arches bears upon about one-third of the circumference of this pin.

The design of this foot-bridge was influenced by the fact that the traffic on the Seine, at this point, is very dense, and it was necessary to devise means of erection that would not interfere with this traffic. The cantilever type of bridge was, therefore, selected; and the members were put in place by means of a traveler and suspended platforms. During the erection of the center span, temporary tie-rods were used, leading from the top of the second suspender, beyond the floor intersection to the point where the bottom chord of the floor system meets the top chord of the shore semi-arch. To reduce to a minimum the weight of the traveler, and to facilitate their movement, the winches were placed on the bridge floor, behind the traveler. These arches were framed about 4 ins. higher than the final elevation of the crown, so as to facilitate the connection at the crown; it should also be said that 40 tons of ballast had been placed upon the shore span, to assist in this operation and as a measure of security. The original article in "Le Genie Civil," from which Figs. 1 to 5 are reproduced, gives the detailed dimensions of the members of this bridge, and also the method by which the arches were calculated. Fig. 6 is a view of the structure looking toward the Army and Navy Building, and gives some idea of its graceful appearance and pleasing proportions. We are indebted for this view to our German contemporary, the "Zeitschrift des Vereines deutscher Ingenieure."

BOOK REVIEWS.

THE WATER SUPPLY OF THE CITY OF NEW YORK.—An Inquiry into the Conditions Relating Thereto, by the Merchants' Association of New York. 8vo.; cloth; pp. 627, with numerous maps and plates. $3.

We reviewed at much length last week, from advance proofs, this important and most valuable report. The complete bound volume is now before us, together with an announcement of the conditions under which distribution

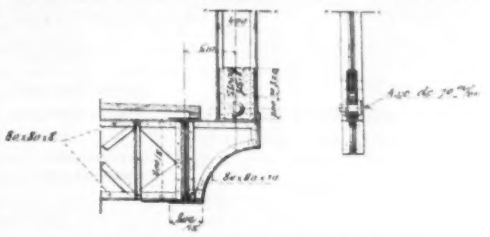

Fig. 4.—Details of Floor Beam and Hanger.

will be made. It will be readily understood that the report is published primarily to instruct public opinion in relation to New York's water supply. The committee have received, however, a great number of requests from engineers for copies of the work, and desire to accede to such requests so far as the supply of copies available will permit. A price of $3 has been set upon the volume, therefore, and a copy will be sent, charges prepaid, to any one forwarding that amount. Orders should be addressed to Mr. S. Cristy Mead, Asst. Secy. Merchants' Association, 346 Broadway, New York city.

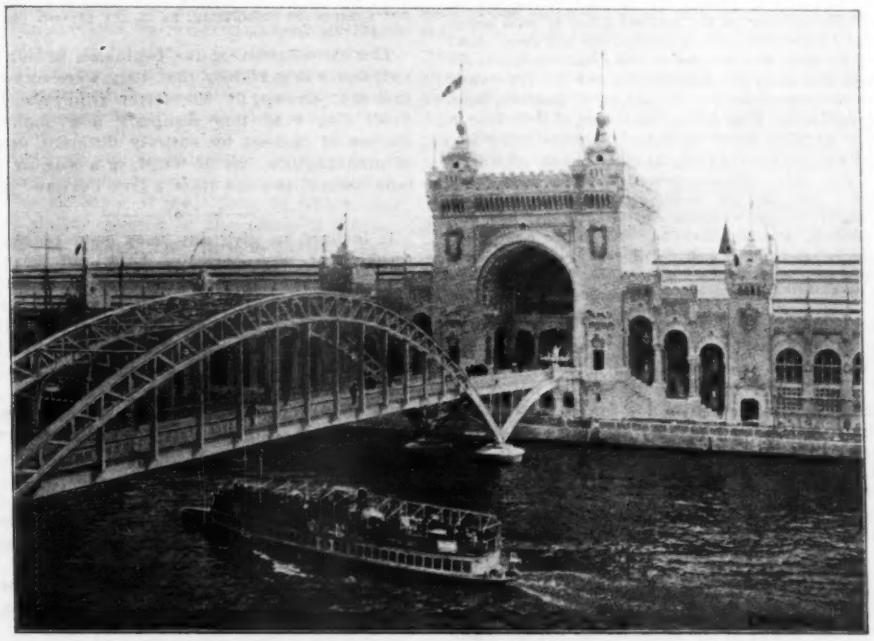

FIG. 6.—VIEW OF FOOTBRIDGE OVER THE SEINE AT THE PARIS EXPOSITION, BY THE ARMY AND NAVY BUILDING.

ACETYLENE FOR RAILWAY STATION LIGHTING is being introduced by the Great Northern Ry. At Hamline, Minn., a freight transfer house 800 ft. long is lit with 100 lamps at a cost of about 0.55 ct. to 0.65 ct. per lamp hour. The generator used is charged with carbide every other day and the cost of handling freight has been reduced through the improved illumination. Particulars

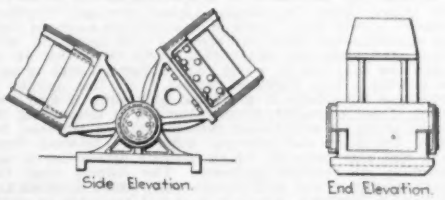

Fig. 5.—Details of Hinges at Abutments.

of this and other applications of acetylene in railway service are given in a paper by Mr. A. Lipschutz, read before the Civil Engineers' Society of St. Paul and published in the "Journal of the Association of Engineering Societies" for June.

ENGINEERING NEWS
AND
AMERICAN RAILWAY JOURNAL.

Entered at the New York Post-Office as Second-Class Matter.
Published every Thursday
at St. Paul Building, 220 Broadway, New York, by
THE ENGINEERING NEWS PUBLISHING COMPANY

GEO. H. FROST, - - - - - - - - - PRESIDENT.
D. McN. STAUFFER, - - - - - - - VICE-PRESIDENT.
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ALFRED E. KORNFELD, New York,
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PUBLICATION OFFICE, 220 BROADWAY, NEW YORK.
CHICAGO OFFICE, 1636 MONADNOCK BLOCK.
BOSTON OFFICE, 170 SUMMER ST.
CLEVELAND OFFICE, OSBORN BUILDING.
LONDON OFFICE, EFFINGHAM HOUSE, 1 ARUNDEL ST., STRAND.

SUBSCRIPTION RATES: United States, Canada and Mexico, One Year, $5.00; 6 months, $2.50; 2 months, $1.00. To all other countries in the Postal Union: Regular Edition, One Year, $7.00 (31 shillings); Thin Paper Edition, One Year, $6.31 (26 shillings). SINGLE COPIES of any number in current year, 15 cents.

In requesting change of mailing address, state BOTH old and new address; notice of change should reach us by Tuesday to be effective for the issue of the current week. The number on the address label of each paper indicates when subscription expires, the last figure indicating the year and the one or two preceding figures the week of that year; for instance, the number 320 means that subscription is paid to the 32d week (that is the issue of Aug. 9) of the year 1900; the change of these figures is the only receipt, unless one is sent by special request.

ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXI-XXIII. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

The complete bound volume of the Merchants' Association Report on the New York water supply, which we reviewed at length last week, has now been issued from the press. A notice regarding the arrangement made for its distribution is published under the head of "Book Reviews" on page 147; and we call attention to it here to advise those in charge of engineering and scientific libraries to be sure and obtain a copy of the work before the edition is exhausted.

In our issue of June 7, in discussing briefly the different kinds of raw materials used for making Portland cement, we mentioned the existence of a plant at the works of the Illinois Steel Co. for manufacturing Portland cement from blast furnace slag and limestone. A number of correspondents have called our attention to what they consider to be an error in this statement, and requested that in the interest of accuracy we should correct it. The following letter from a prominent engineer summarizes quite fairly the claims of these correspondents, and we therefore print it alone. It is as follows:

> Sir: In your issue of June 7, speaking of the product of the Illinois Steel Co., South Chicago, you say "Portland cement is now being made in considerable amounts from an admixture of blast furnace slag and limestone, etc., etc.", and state also that "this works is, so far as we know the only one in which that material (slag) is used in making a true Portland cement." As this opinion is expressed editorially in a journal of repute, it may possibly, if not corrected, be mischievous in misleading the public about an erroneously labeled building material, for there are many and essential differences between Portland and slag cements, which indicate differences in application for building purposes. The Illinois Steel Co. manufactures a true slag cement only, which it labels and sells as a Portland, which it does not resemble in characteristic qualities. In this connection I take the liberty to send you a report of a Board of Engineers upon this particular slag cement, just published by the U. S. Government.

In order to clear ourselves of this imputation of error in the statement made in our issue of June 7, we made particular inquiry of the Illinois Steel Co. concerning the matter, and received the following letter in answer:

> Sir: In reply to your letter of June 27, I beg to state that we are making a true Portland cement at our new works at South Chicago, inasmuch as we pulverize slag and limestone together in proper proportions, then burn the mixture to a clinker in a rotary kiln. This clinker is afterwards thoroughly ground and the cement is essentially of the same composition, both chemical and physical, as the Lehigh Valley brands. We have also manufactured, for some five years, and shall continue to do so at both our works, a slag cement made by a process in which a mixture of granulated slag and thoroughly slaked lime is ground, without calcination after mixing.
>
> Yours very truly,
> Edward M. Hagar, Manager.
> Chicago, Ill., July 6, 1900.

Commenting upon this letter, we may say that we were fully aware that the Illinois Steel Co. manufactured a slag cement to which they had given the somewhat misleading trade name of "Steel Portland Cement." We also knew that in addition to their slag cement plant the company had installed more recently a plant for making Portland cement from a mixture of limestone and slag ground together and afterwards calcined to clinker and reground in the regular manner of Portland cement manufacture. In order to clinch the accuracy of our terminology in so far as it is criticised by our correspondents, we quote the following passage from the Government report referred to in the first letter printed above:

> In the manufacture of hydraulic cement, authorities agree that the method of manufacture is of the utmost importance in determining the quality and class of the final product, and that a mere chemical analysis of the final product does not determine the properties possessed by the resulting cement. Spalding especially calls attention to the fact that a Portland cement may be made from pulverized burnt argillaceous and calcareous materials mixed with powdered slaked lime, provided that the mixture be properly calcined afterwards. In other words, it is possible to make a Portland cement from slag and lime, but not by the method of mechanical mixture without subsequent calcination, as in the present practice of the Illinois Steel Co.

The explanation of the confusion of our correspondents is evidently that they were unaware of the fact shown by the letter from the Illinois Steel Co., that this company now makes two classes of cement by entirely different processes of manufacture, one of which is a slag or puzzolana cement and the other a true Portland cement.

It is hard to give any very good reasons why mechanical pipe scrapers have not been used more extensively for cleaning water mains in American cities. The practice is much more common in England than on this side of the Atlantic. In fact, besides Halifax, N. S., St. John, N. B., and Boston, Mass., we do not now recall any water-works on this continent that have made more than experimental use of these devices. In our issues of July 20 and 27, 1899, we gave accounts of the use of such scrapers at St. John, N. B., and at Boston, and in our last issue we gave some figures relating to 20 years of experience at Halifax, N. S., drawn from the last report of Mr. F. W. W. Doane, City Engineer of Halifax. If any of our readers know of other American cities where pipe scrapers have been or are being used we should be pleased to hear from them.

We print in this issue an interesting review of English experience in this field, which brings out very clearly the systematic manner in which pipe scraping is carried on abroad and the benefits resulting therefrom. It will be noted that water from both peaty and granitic drainage areas is held liable to give rise to corrosion; also that the relative effects of corrosion on cast iron, wrought iron and steel pipes is placed at 100, 129 and 133, respectively.

Still another noteworthy statement, in view of recent public utterances on the same subject, is that filtered water causes less corrosion than unfiltered water. English experience with filtered water supplies has been so extensive that such a statement may be taken as authoritative.

The learned opinion of Water Commissioner Dalton, of New York city, to the effect that: "It would be out of the question to attempt to carry filtered water through lead pipes," etc. (quoted in our last issue, p. 128), has been elaborated and explained by the "New York Times" as follows:

> One reason why cleaning the slimy accumulations from the inside of lead mains would charge the water passing through them with poisonous tin flakes is that this slime, being vitreous and consequently insoluble in anything but interplanetary other, acts as a protecting coating to the metal, forming with it a compound carbophosphate of zinc, which arsorbs argon from the water and, by chemical union with antimony, would give off hyposulphide of bismuth, which, as is well known, has a great affinity for helium. To filter the water would cause it to enter the mains comparatively clean, and any fool knows that clean water is wholly unfit for drinking purposes. Water in passing through tin mains it would reach the consumer loaded with chunks of iridium, and the subsequent use of gallium generated in the stomach would cause a frightful mortality from sodium poisoning. These facts would not have escaped the Commissioner's notice, but his statement would have been equally instructive and more complete if he had included them.

STANDARDS OF TRACK CONSTRUCTION ON AMERICAN RAILWAYS.

In the earlier days of American railways there was great diversity of practice in design of material and methods of work, due in part to the lack of means of interchange of knowledge and in part to the general idea that each man should impress his individuality upon his work by the use of devices or methods different from those employed by other men. With the advance of technical knowledge and the means of widely disseminating this knowledge, there has been in track work as in other branches of railway and engineering work, a decided tendency towards the adoption of standards and uniformity in materials and methods. About four years ago we published tabular statements showing the standard practice of track construction then in force on some fifty railways in the United States. In another part of this issue we present similar but more extended statements representing the standard practice now in force, these tables being supplemented by explanatory notes and additional information. During the four years that have elapsed since the first set of tables was prepared, considerable changes have been made, and in certain respects there has been a decided increase in the adoption of uniform standards to supersede individual ideas and preferences. It will, of course, be understood that the standards described, and which were officially stated to us by the chief engineers of the various lines, do not represent the actual construction on the entire mileage of these lines. They represent, however, the style of construction which is now the adopted standard, and which is therefore gradually replacing other older and lighter materials and track construction. It will be of interest at this time to consider some of the special features brought out by a consideration of the tables of track construction for 1900.

Taking the rails as the first item for consideration, the extent to which the type of section recommended by the rail committee of the American Society of Civil Engineers has been adopted is very striking. About 60 per cent. of the railways included in our list (including the two great Canadian systems, but exclusive of Mexico) have adopted these sections as their standard, while in 1896 only 10 per cent. of the railways listed had adopted them. The total mileage of the railways on the present list is about 120,000 miles, of which 75 per cent. is represented by the lines which have adopted the Am. Soc. C. E. section. This, of course, does not mean that rails of this section are actually laid on any such mileage as yet, but that it is the adopted standard which is already laid to a greater or less extent and is being used for all new work and renewals. Of the other sections in use, many (including those of the Dudley type) are based on the principles underlying the design of the Am. Soc. C. E. section, and one of the most important features of all these sections is the use of a comparatively broad and shallow head with sharp top corners. The Pennsylvania R. R. is practically the only important railway which still adheres to the old-fashioned section having a thick head with corners of large radius. Many minor roads use rails of this latter type, but the general tendency on such roads also is to purchase new rails of the Am. Soc. C. E. type.

With the exception of a 56-lb. rail for the narrow-gage Mexican Interoceanic Ry., the lightest main line rail mentioned is 60 lbs. per yd., but most of the main lines have rails of 75 and 80 lbs. per yd. at least. Where two weights are given in the table, it will be understood that the lighter rail is for inferior lines. Another interesting feature is the extent to which a length of 33 ft. has been adopted as standard. Several railways are

using rails 60 ft. in length in special cases, but none have adopted this as standard, while the Lehigh Valley R. R. and Philadelphia & Reading R. R. have 45-ft. rails, though the standard length is 30 ft. In our tables published in 1896, one road (the Louisville, New Albany & Chicago Ry., now reorganized as the Chicago, Indianapolis & Louisville Ry.) was mentioned as having rails 33 ft. long. In our present table, however, this length is shown as being standard on eight railways.

As to rail fastenings, the showing is distinctly unsatisfactory, there being no change from the old spike, whose deficiencies (especially for track carrying heavy traffic) are well and widely recognized. Spikes of improved manufacture, having sharp points or cutting edges, and clean smooth surfaces for the shank, are being somewhat extensively used, but apart from this the rail fastening remains practically as it was 20 or 50 years ago. The usual size of the spike is 9-16-in. square, 5½ ins. long under the head, and 6 ins. over all. The interlocking bolt and other bolt fastenings appear to be very little used now, even on bridge floors. Only one road is experimenting with screw spikes, while two others have abandoned them after some trials. What is now needed is a fastening which will hold the rail rigidly to the tie, and we might learn much in this respect from European practice, where the screw spike is a standard device for track laid with T rails.

In regard to rail joints, the extent of track laid with suspended and broken joints far exceeds that laid with supported joints and square joints. Many roads are using various forms of bridge joints, and a few have adopted such a form as standard, but in most cases they are regarded mainly as experimental or incidental. Only three roads report the three-tie joint as standard, and only eight report the supported joint. As to the practice regarding square or broken joints, the latter is now almost universally followed. Only six roads still adhere to the former, while two use both systems on different parts of their lines, and four lay their rails with square joints on tangents and broken joints on curves. The length of splice bars shows a tendency to decrease, and there are now very few of more than 36 ins. As between four-bolt and six-bolt joints, the railways are almost equally divided, the length of splice bars ranging from 20 to 26 ins. for the former and from 26 to 42 ins. for the latter. The latest splice bars for the 100-lb. rails of the Pennsylvania R. R. are 30 ins. long, instead of 34 ins., as formerly. The Union Pacific Ry. is also proposing to adopt a 29-in. bar with six bolts. It is evident that close spacing of the bolts and a shortening of the joint as a whole are now much more generally approved than they were some years ago. Several railways use a 6-in. spacing for the bolts, and a few go as far as 7 or 8 ins., but beyond this the only example is the 9-in. outer spacing of the six-bolt joints of the Illinois Central R. R. On the other hand, the closest spacing is 3⅜ ins. and 4 ins. As to the track bolts, the diameter is almost universally ¾-in., or ⅞-in., though the Grand Trunk Ry. and the Pennsylvania R. R. have adopted a 1-in. bolt, the latter road using this size for 100-lb. rails only. Square nuts are used on about 75 per cent. of the lines and hexagonal nuts on the others. Many use the grip-thread bolts, with nuts automatically locked, but where ordinary bolts are used, spiral washers or nut locks of various makes are usually applied.

The returns as to the ties used admit of but little summarizing, but we have been careful to show in most cases the sources from which the different kinds of timbers are obtained. Records of this kind are usually classified simply by the kinds of timber, but this is not sufficient for accurate records of the life and economy of ties. For instance, we find that oak from the south and southwest has a life of 6 to 7 years, while oak from the northern part of the country has a life of 10 to 14 years. The most general length is 8 ft., but very many roads adopt 8½ ft., while on southern lines a length of 9 ft. is common. The usual number of ties per 30-ft. rail is from 16 to 18, though the Grand Trunk Ry. uses as many as 19 and the Pennsylvania R. R. uses only 14. On the latter road, however, the ties are usually of exceptional width. The cost is very variable, depending upon the quality of the timber and the cost of transportation. Thus, oak ties range from 25 to 70 cts.; cedar, 22 to 25 cts.; and yellow pine, 28 to 70 cts. The Mexican Interoceanic Ry. (3 ft. 6 ins. gage) is using English steel ties at $2.25 each (Mexican money), with an estimated life of 30 years; and also ties of Australian jarrah wood at $2 each (Mexican money), with a guaranteed life of 15 years. The showing as to the use of ties treated by preservative processes is not as good as it should be, in view of the well proved advantages and economy of these ties. It seems probable, however, that in a few years these advantages, together with the increased prices of green or untreated ties, will lead to a much more general adoption of treated ties. On the other hand, steel tie-plates continue to be very generally used. Only three roads report that these plates are not used. Of the others, some use them only on curves, or only on soft ties (sometimes on all ties and sometimes on alternate ties), while others use them much more generally. One road, the Kansas City, Fort Scott & Memphis Ry., reports that their use has been discontinued, except on bad curves. The majority of these used are of the flanged type, of different makes. The claw pattern is represented only by one make, and the Pennsylvania R. R. still uses some flat plates, which are obsolete nearly everywhere else.

Gravel ballast, including all the various qualities which that term covers, is probably used more than any other material, although stone ranks probably a close second to first-class gravel. Slag is used on many roads, and burnt clay is quite common on western railways. The standard depth of ballast under the ties rarely exceeds 12 ins., but there are many cases where it would be wise and economical to raise the track and give a greater depth of a better quality of ballast.

Coming now to the consideration of frogs and switches, we find the bolted frog in very general favor. The old style of plate frog, in which the rails were simply riveted to the plate, is disappearing, but in several cases a combination type of frog is approved, having the rails bolted or clamped together (using the ordinary form of flange filler) and riveted to a base plate. This makes a very substantial construction to withstand the effects of heavy traffic. Spring rail frogs are almost universally used in main line turnouts, only four or five roads still continuing to discountenance this type. Presumably the objections are mainly on the ground of greater safety with rigid frogs, but this objection will hardly hold good in the light of the very extensive experience with spring-rail frogs under the fastest and heaviest classes of traffic. For main track, the standard frogs are usually Nos. 9 and 10, with smaller numbers occasionally, and Nos. 14 to 24 for special cases, where the turnouts are used at high speed. Thus the Pennsylvania R. R. uses No. 24 frogs in some cases, while the Chesapeake & Ohio Ry., and the Cleveland, Cincinnati, Chicago & St. Louis Ry. use No. 14 and No. 18 respectively at the ends of double track sections. Rigid frogs are commonly used in yards, and to a large extent on branches and inferior lines. For yard purposes, Nos. 6 to 9 are the most generally used.

The split switch is now practically universal in main track work, though a few roads still adhere to the Wharton switch as a standard. The split switch is also very commonly used in yard tracks, where, however, the stub switch is still frequently to be met with, even on roads where its use would hardly be expected. The most common length of switch rail for split switches is 15 ft., while several roads use 18 ft. The Norfolk & Western R. R. has changed from 18 ft. to 15 ft., but of course still has a number of the former in use. Lengths of 19½, 20, 21, 24, 28 and 30 ft. are also reported, the latter being used by the Cleveland, Cincinnati, Chicago & St. Louis Ry. for switches at the ends of double track sections. The Lake Shore & Michigan Southern Ry. reports lengths of 10, 12, and 15 ft., but it is hardly likely that the two former are used in high-speed main tracks. Lengths of 10 to 15 ft. are usually employed for yard switches. The practice as to the use of rigid or automatic switchstands seems about equally divided, except that in many cases the switchstands are locked so as to be rigid when set for the main track. In other words, a main line train can safely trail through a switch left set for the siding, but a train on the siding cannot trail through a switch set for the main track. The use of a spring in the switch rod, as in the Lorenz switch, is standard on only two of the fifty railways in the list: the Nashville, Chattanooga & St. Louis Ry., and the Pennsylvania R. R. On many important roads the main line turnouts are protected by distant signals, especially in cases where owing to a curve or obstruction the switch target cannot be seen at a distance by the engineman of an approaching train.

So many deaths and injuries to employees have occurred from the men getting their feet caught under the rail heads in the angles at the heels of frogs and switches and at the flaring ends of frog guard rails, that it is now recognized that it is a humane and economical precaution to fill in such places so that a man's foot cannot get caught in the space below the rail head. Wooden blocking is the most common form of footguard, but has the disadvantage that it becomes broken and decayed, and is apt to be left neglected in such a condition. Gravel or cinder filling is also sometimes employed, but soon settles down or shakes out so as to lose its efficiency. Metal foot-guards are preferable, and several forms, patented and otherwise, are in use. In some frogs a special heel-filler or raising block acts also as a footguard. The Hart footguard, frequently mentioned in the tables, consists of a strip of wood of triangular section bolted to the inner side of the web of each rail. The outer (sloping) face of the wood extends from the bottom of the rail head to beyond the edge of the rail base, so that a man's foot cannot get under the rail head.

One other point to which we may refer, is the use of guard rails on curves. This is more common on the sharp curves in yard tracks and sidings than on main track, and the practice is very diverse. They are used on all curves sharper than 10° or 12° on some lines, and 20° to 25° on others. The width of flangeway ranges from 1¾ ins. plus the amount of widening of gage on the curve, to 2½ and 3 ins., and even 5 ins.

Taken as a whole, the standards described in the tables show that the principal main lines at least have a sufficiently substantial form of track construction for the high-speed passenger trains and the enormously heavy freight trains which are now such a feature of American railway service. On many of the less important lines the construction is equally good. No road has as yet made any experiments with a permanent construction of roadbed, as suggested and described in our issues of Jan. 5 and March 23, 1899, but the universal type of construction is that in which the rails are spiked to wooden cross-ties laid in a bed of loose material or ballast. Treated ties and improved fastenings to the ties are the improvements most urgently needed, and a concrete roadbed construction may perhaps follow.

LETTERS TO THE EDITOR.

Comparative Cost of Water Filtration at Albany and Lawrence.—General Specifications for the Wildwood Pumping Engine.

Sir: Two days before the receipt of Engineering News of Aug. 9, I received an annual report of the Lawrence, Mass., Water Board, and I was interested to make a comparison between the costs of filtering water at Albany, N. Y., and Lawrence, Mass. From the two statements I compile the following table:

Cost of Operation of Filter Beds, per 1,000,000 gallons.

	1,102,000,000 gallons filtered. Lawrence, Mass.	3,687,000,000 gallons filtered. Albany, N. Y.
Ice cutting and snow	$0.20	....
Scraping	....	$0.25
Sanding and scraping	0.34	....
Wheeling out	....	0.50
Washing sand	0.13	0.54
Conveying sand	0.14	....
Refilling	....	0.39
Incidentals	0.06	0.26
Total cost per 1,000,000 gallons filtered	$0.87	$1.94

The terms used in these reports differ somewhat from each other. I endeavored, however, while using the terms

used by each, to so place them in the table as to show as near as may be the cost of the same items. You will notice that the "scraping" and "wheeling out" of the Albany plant is apparently comparable with the sanding and scraping of the Lawrence plant, and that the Albany plant is more than twice as expensive as the Lawrence plant. In the washing of sand the Albany plant is four times as expensive. In the conveying of sand at Lawrence and the refilling at Albany, the Albany plant is nearly three times as expensive as the Lawrence. For incidentals the Albany plant is four times as expensive. The Albany plant does not have to consider the question of ice and snow. In the aggregate the Albany plant is costing more than twice as much per million gallons filtered as at Lawrence.

In all probability the political influences in these two places would be about the same. If the Albany plant could be run as cheaply as the Lawrence plant, there would be a saving of nearly $4,000 per year. This, to a private water company, would be quite an item, and would be equal to the dividend of 5% on $80,000 investment. I presume there may be some explanation for these differences.

I note in your issue of August 23 quite an article on the Nordberg pumping engine at Wildwood, Pa., erected for the Pennsylvania Water Co. As an engineer's reputation must be judged from his work, I desire to call your attention to the fact that this pump was designed from general specifications written by the undersigned as President and Chief Engineer of the said Pennsylvania Water Co. While all due credit should be given to Mr. Nordberg for his production, and to Prof. Carpenter for the tests of the engine, still I think the undersigned is entitled to a little credit.

Respectfully yours, James H. Harlow.

Wilkinsburg, Pa., Aug. 25, 1900.

Notes and Queries.

In the report of the test of the Allis pumping engine in our last issue, on page 126, middle of second column, the figure for average pressure in the 2d receiver should be — 3.31 instead of 3.31 lbs. per sq. in. That is the pressure in the receiver was 3.31 lbs. below atmospheric pressure.

K. C. S. asks for methods of re-running old compound curves in the track when no starting points can be found except the intersection of the two tangents.

CONSOLIDATION LOCOMOTIVES FOR THE RIO GRANDE WESTERN RY.

(With two-page plate.)

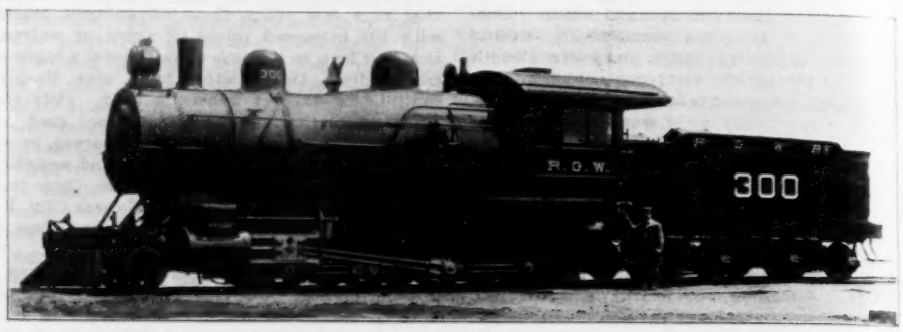
We illustrate on our inset sheet this week and in the accompanying cuts a new consolidation locomotive, eight of which have recently been built for the Rio Grande Western Ry. by the Richmond Locomotive Works. While this engine is not as large as some of the huge machines built for Eastern railways during the past two or three years, it is a very large and powerful locomotive, and is a good illustration of the extent to which locomotives of the heaviest class are being adopted by the smaller railways to replace the lighter rolling stock of an earlier period. Four of these engines have 56-in. drivers, and the other four 50-in.; but in every other particular the eight are exact duplicates of each other.

As will be remembered by many of our readers, the Rio Grande Western Ry. forms the western connection of the Denver & Rio Grande system, extending from Grand Junction, Colorado, to Salt Lake and Ogden, Utah. During the past ten years its traffic has largely increased, especially in the handling of coal and other minerals from the Utah mining districts, and it now handles about double the tonnage that it did ten years ago. These new locomotives are doubtless intended for the more economical haulage of heavy freight trains.

The cylinders of the new locomotive are 22 × 28 ins., and the boiler will be seen by the perspective view to be of very large capacity. It is of the radial stay type, with the crown sheet sloping toward the back. This latter detail is of especial importance on a road of steep grades, where a level crown sheet is apt to be left bare when the engine pitches over a summit. The firebox is placed over the frames, giving a width of 41 ins. for the grates, and the ample height and spreading sides of the firebox give room for good combustion with the long-flaming Western coal, and also a large area of direct heating surface, to promote free steaming. The tubes are 2¼ ins. in diameter and 14 ft. 3 ins. long. It will be seen that they are arranged in vertical and horizontal rows instead of being staggered, as in ordinary practice. The stay bolts are all turned down smooth between the sheets, and their outer ends are drilled with telltale holes ⅛-in. diameter and 1¼-in. deep. The dome has a welded seam, and the dome-sheet is heavily reinforced around the dome ring. The boiler barrel is 82 ins. in diameter at the dome, which makes the circumferential tensile stress per lineal inch of the boiler, at 200 lbs. pressure, 8,200 lbs., or 9,500 lbs. per sq. in. of cross-section of the 13-16-in. plate used for this ring.

The running gear is thoroughly substantial. Cast-steel wheel centers are used for the driving wheels and large and long bearings (9 × 12 ins.) are provided to ensure cool running. The second and third pairs of drivers have blind tires. A hint of the mountain grades over which the engines are to do service is given by the large air reservoir capacity for the air brake supply. There are two of these reservoirs, one on each side of the engine, and each is 16 ins. diameter and 10 ft. 6 ins. long. The volume of air thus stored is an important safeguard in handling trains down mountain grades where frequent applications and releases are necessary to keep the train moving rapidly, yet without exceeding safe limits of speed.

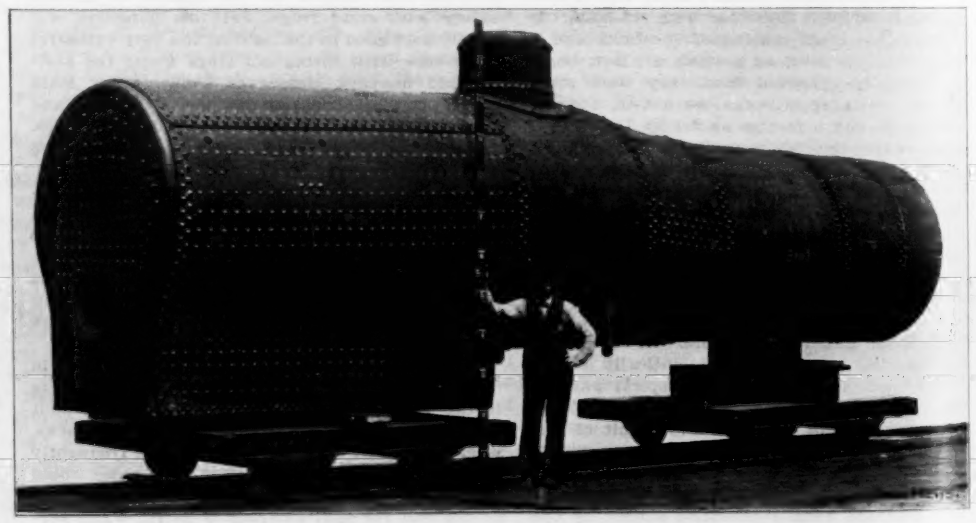
The principal dimensions of these locomotives are given in the table below in our standard form. We are indebted to Mr. W. R. Williamson, Secretary of the Richmond Locomotive & Machine Works, for the information from which this article has been prepared, and for the drawings and photographs from which our illustrations are reproduced.



CONSOLIDATION LOCOMOTIVE FOR THE RIO GRANDE WESTERN RY.
Richmond Locomotive & Machine Works, Richmond, Va., Builders.

Wheelbase: Driving	16 ft. 8 ins.
Total engine	24 " 11 "
Tender	17 ft. 11 ins.; engine and tender 52 " 11 "
Center of engine truck-pin to center of leading driving wheel	8 ft. 3 "
Weight in Working Order:	
On driving whls.	168,400 lbs.; on truck whls. 16,600 lbs.
Total engine	185,000 "
Tender, empty	43,200 lbs.; loaded 100,850 "
Water in tank	41,650 lbs.; in boiler 21,000 "
Coal on tender	16,000 "
Weight of piston and rod	575 "
Crosshead,	380 lbs.; main rd. 770 lbs.; side rd. 577 "
Cylinders	22 × 28 ins.
Cubic contents of both cylinders	12.64 cu. ft.
Form of crosshead guides	2-bar, "H" type.
Connecting rod, length between centers	10 ft. 9¾ ins.
Side rod	Solid end.
Valve Gear:	
Ports, steam	1⅝×21 ins.; exhaust 3¼×21 ins.
Bridges, width	1½ " ; eccentrics, throw 5½ "
Slide valves, style	Richardson balanced
Maximum travel	6 "
Inside lap	None; outside lap 1-in.
lead (full forward gear	1-32-in.
lead (full backward gear)	1-32-in.

View Inside of Smoke-Box.



BOILER FOR RIO GRANDE WESTERN CONSOLIDATION LOCOMOTIVE.

Boiler: Type	Extended wagon-top.
Diameter barrel, outside smallest ring	6 ft. 2 ins.
Dome, diameter	2 ft. 0½ ins.
Thickness, barrel plates	¾-in. and 13-16-in.
Smokebox tube plate	½-in.
Horizontal seams	Sextuple riveted; butt joints
Circumferential seams	Double riveted.
Rivets, diameter	1⅛ ins.
Height from rail to center line	8 ft. 7 ins.
Length, smokebox, including extension	5 ft. 11 5-16 ins.
Spark arresting device	M. M. Assoc style; wire netting and deflector plates.
Injectors, number	2; Ohio.
Working steam pressure	185 lbs.

Fire... type	Sloping, radial stayed.
... inside	10 ft. 2 ins.; width inside, 3 ft. 5 1-16 ins.
... front	6 ft. 5¼ ins.; depth at back, 5 ft. 11 "
... side, back and crown plates	11-32-in.
Thickness, tube plate	½-in.
... crown stays	1⅛ ins.
... of grate bars	Cast-iron rocking, finger.
... bolts	Drilled ends; diameter, 15-16-in. and 1-in.
... water spaces, width at front	4½ ins.
... " at back and sides	4 "
Tubes, Material	Iron; Number, 318
... thickness	No. 12 B.W.G.; Pitch, about, 3 ins.
... diameter, outside	2¼ "
... length over tube plates	14 ft. 2⅞ "
... total area of tube openings	6.24 sq. ft.
Heating Surface and Grate Area:	
Heating surface, tubes (interior area)	2,667.0 sq. ft.
" " firebox	206.0 "
" " total	2,873.0 "
Grate area	34.7 "
Ratio, total heating surface to grate area	1 to 82.79
" interior tube area to firebox heatg surf.	1 " 11.53
Sq. ft. of total htg surf. to 1 cu. ft. cyl. vol.	1 " 227.3
" of firebox heatg surf. to 1 cu. ft. cyl. vol.	1 " 16.28
" of tube heatg surf. to 1 cu. ft. cyl. vol.	1 " 210.9
" of grate area to 1 cu. ft. cylinder volume	1 " 2.74
Miscellaneous:	
Exhaust nozzle	Single; diameter, 5½ ins.
Exhaust nozzle, below center line of boiler	4⅛ "
Smokestack, diameter at top	17½ "
" diameter at base	15 "
" height of top above rail	14 ft. 8½ "
Capacity of tender tank	5,000 galls.
Capacity of coal space	8 tons.
Brake fittings	American and Westinghouse.
Tractive force per lb. of effective pressure on piston	1 to 242.69
Total tractive force with effective pressure equal to 85% of boiler pressure	38,154 lbs.
Total adhesive tractive power at ¼ of weight on driving wheels	42,100 "
Ratio of tractive force to weight on driving wheels	22%

THE MACHINERY EMPLOYED AND METHODS OF CONSTRUCTION ADOPTED AT THE SIMPLON TUNNEL.*

By Charles Beresford Fox.

Before entering upon a description of the constructive details of this, the longest railway tunnel in the world, it may be well to give a general idea of the undertaking. Many schemes for the connection of Italy and Switzerland by a railway near the Simplon Road Pass have been devised, including one involving no great length of underground work, the line mounting by steep gradients and sharp curves. The present scheme, put forward in 1881 by the Jura-Simplon Ry. Co., consists broadly of piercing the Alps between Brigue, the present railway terminus in the Rhone Valley, and Iselle, in the gorge of the Diveria, on the Italian side, from which village the railway will descend to the existing southern terminus at Domo d'Ossola, a distance of about 11 miles.

In conjunction with this scheme a second tunnel is proposed, to pierce the Bernese Alps under the Lötschen Pass from Mitthoiz to a point near Turtman in the Rhone Valley, and thus, instead of the long detour by Lausanne and the Lake of Geneva, there will be an almost direct line from Berne to Milan via Thun, Brigue, and Domo d'Ossola.

Starting from Brigue, the new line, running gently up the valley for 1¼ miles, will, on account of the proximity of the Rhone, which has already been slightly diverted, enter the tunnels on a curve to the right, of 1,050 ft. radius. At a distance of 153 yards from the entrance the straight portion of the tunnels commences and extends for 12 miles. The line then curves to the left with a radius of 1,311 ft. before emerging on the left bank of the Diveria. Commencing at the northern entrance, a gradient of 1 in 500 (the minimum for efficient drainage) rises for a length of 5½ miles to a level length of 550 yards in the center, and then a gradient of 1 in 143 descends to the Italian side. On the way to Domo d'Ossola one helical tunnel will be necessary, as has been carried out on the St. Gothard. There will be eventually two parallel tunnels, having their centers 56 ft. apart, each carrying one line of way, but at the present time only one heading, that known as No. 1, is being excavated to full size, No. 2 being left, masonry lined where necessary, for future developments. By means of cross headings every 220 yds. the problems of transport and ventilation are greatly facilitated, as will be seen later. As both entrances are on curves, a small "gallery of direction" is necessary, to allow corrections of alinement to be made direct from the two observatories on the axis of the tunnel.

The outside installations are as nearly in duplicate as circumstances will allow, and consist of the necessary offices, workshops, engine-sheds, power-houses, smithies, and the numerous buildings entailed by an important engineering scheme. Great care is taken that the miners and men working in the tunnel shall not suffer from the sudden change from the warm headings to the cold Alpine air outside, and for this purpose a large building is in course of erection, where they will be able to take off their damp working clothes, have a hot and cold douche, put on a warm dry suit, and obtain refreshments at a moderate cost before returning to their homes. Instead of each man having a locker in which to stow his clothes, a perfect forest of cords hang down from the wooden ceiling, 25 ft. above floor-level, each cord passing over its own pulleys and down the wall to a numbered belaying pin. Each cord supports three hooks and a soap-dish, which, when loaded with their owner's property, are hauled up to the ceiling out of the way. There are 2,000 of these cords, spaced 1 ft. 6 ins. apart, one to each man. The engineers and foremen are more privileged, being provided with dressing-rooms and baths, partitioned off from the two main halls. An extensive clothes-washing and drying plant has been laid down, and also a large restaurant and canteen. At Iselle, a magazine holding 2,200 lbs. of dynamite is surrounded and divided into two separate parts by earth-banks, 16 ft. high. The two wooden houses, in which the explosive is stored, are warmed by hot-water pipes to a temperature between 61° F. and 77° F. and are watched by a military patrol, but at Brigue a dynamite manufactory, started by an enterprising company at the time of the commencement of the works, supplies this commodity at frequent intervals, thereby avoiding the necessity of storing in such large quantities. This dynamite factory has been largely increased, and supplies dynamite to nearly all the mining and tunnelling enterprises in Switzerland.

*Abstract of a paper read before the Institution of Civil Engineers of Great Britain.

Geological Conditions.—Before the Simplon Tunnel was authorized, expert evidence was taken as to the feasibility of the project. The forecasts of the three engineers chosen, in reference to the rock to be encountered and its probable temperature, have, as far as the galleries have gone (an aggregate distance of nearly 2½ miles), generally been found correct. At the north end, a dark argillaceous schist veined with quartz was met with, and from time to time beds of gypsum and dolomite have been traversed, the dip of the strata being on the whole favorable to progress, though timbering is resorted to at dangerous places. Water was plentiful at the commencement; in fact, one inrush has not been stopped, and is still flowing down the heading. The total quantity of water flowing from the tunnel mouth is 16 gallons per second, of which 2 gallons per second are accounted for by the drilling machines. At Iselle, however, a very hard antigorio gneiss obtains, and is likely to extend for 4 miles. Very dry and very compact, it requires no timbering, and presents no great difficulty to the powerful Brandt rock-drills, which work under a head of 3,280 ft. of water.

The temperature of the rock depends not only on the depth from the surface, but largely upon the general form of that surface combined with the conductivity of the rock. Taking these points into consideration with the experience gained from the construction of the St. Gothard Tunnel, 85° F. was estimated as the probable maximum temperature, owing to the height of Monte Leone (11,660 ft.), which lies almost directly over the tunnel axis.

Survey.—After having determined upon the general position of the tunnels, taking into consideration the necessary gradients, the temperature of the rock, and a large bed of troublesome gypsum on the north side, two fixed points on the proposed center line were taken, one at each entrance of tunnel No. 1, and the bearings of these two points, with reference to a triangulation survey made in 1876, were calculated sufficiently accurately to determine, for the time being, the direction of the tunnel. In 1898, a new triangulation survey was made, taking in eleven summits, Monte Leone holding the central position. This survey was tied into that of the Wasenhorn and Faulhorn, made by the Swiss Government, and the accuracy was such that the probable error in the meeting of the two headings is only 6 cms., or 2½ ins.

On the top of each summit is placed a signal, consisting of a small pillar of masonry rounded on rock and capped with a sharp-pointed cone of zinc, 1 ft. 6 ins. high. An observatory was built at each end of the tunnel in such a position that three of the summits could be seen, a condition very difficult to fulfil on the south side owing to the depth of the gorge, the mountains on either side being over 7,000 ft. high. Having taken the angles to and from each visible signal, and therefrom having calculated the direction of the tunnel, it was necessary to fix, with extreme accuracy, signting points on the axis of the tunnel, in order to avoid sighting on to the surrounding peaks for each subsequent correction of the alinement of the galleries. To do this, a theodolite 24 ins. long and 2⅜ ins. in diameter, with a magnifying power of 40 times, was set up in the observatory, and about 100 readings were taken of the angles between the surrounding signals and the required sighting points. In this manner the error likely to occur was diminished to less than 1". Thus at the north end two points were found about 550 yds. before and behind the observatory, while on the south side, owing to the narrowness of the gorge, the points could only be placed at 82 yds. and 126 yds. in front. One of these sighting points consists of a fine scratch ruled on a piece of glass fixed in an iron frame, behind which is placed an acetylene lamp—corrections of alinement are always done by night—the whole being rigidly fixed into a niche cut in the rock and protected from climatic and other disturbing agencies by an iron plate.

Method of Checking Alinement.—The direction of heading No. 1 is checked by experts from the Government Survey Department at Lausanne about three times a year, and for this purpose a transit instrument is set up in the observatory. To avoid loss of time—£200 premium or fine being fixed for every day before or after the contract date of completion—a number of three-legged iron tables are placed at intervals of 1 mile or 2 miles along the axis of tunnel No. 1, and upon each of these is placed a horizontal plane, movable by means of an adjusting screw, in a direction at right angles to the axis, along a graduated scale. On this plane are small sockets, into which the legs of an acetylene lamp and screen, or of the transit instrument, can be quickly and accurately placed. The screen has a vertical slit, 3 ins. in height and variable between 13-16-in. and 3-16-in. in breadth, according to the state of the atmosphere, and at a distance shows a fine thread of light. The instrument, having first been sighted on to the illuminated scratch of the sighting point, is directed up the tunnel, where a thread of light is shown from the first table. With the aid of a telephone this light is adjusted so that its image is exactly coincident with the cross hairs, and the reading on the graduated scale is noted. This is done four or five times, the average of these readings being taken as correct, and the plane is clamped to that average. The instrument is then taken to the first table and is placed quickly and accurately over the point just found (by means of the sockets), and the lamp is carried to the observatory. After first sighting back, a second point is given on the second table, and so on. These points are marked either temporarily in the roof of the heading by a short piece of cord hanging down, or permanently by a brass point held by a small steel cylinder, 8 ins. long and 3 ins. in diameter, embedded in concrete in the rock floor, and protected by a circular casting, also sunk in cement concrete, holding an iron cover resembling that of a small manhole. From time to time the alinement is checked from these points by the engineers, and after each blast the general direction is given by the hand from the temporary points. To check the results of the triangulation survey, astronomical observations have been taken simultaneously at each end. With regard to the levels, those given on the excellent Government surveys have been taken as correct, but they have also been checked over the pass.

Details of Tunnels.—In cross section, tunnel No. 1 is 13 ft. 7 ins. wide at formation level, increasing to 16 ft. 5 ins., with a total height of 18 ft. above rail-level and a cross-sectional area of about 250 sq. ft. This large section will allow of small repairs being executed in the roof without interruption of the traffic, and will also allow of strengthening the walls by additional masonry on the inside. The thickness of the lining, never wholly absent, and the material of which it is composed, depend upon the pressure to be resisted, and only in the worst case is an invert resorted to. The side drain, to which the rock floor is made to slope, will be composed of half pipes of 7 to 1 cement concrete. The roof is constructed of radial stones.

Tunnel No. 2, being left as a heading, is driven on that side nearest to No. 1, to minimize the length of the cross headings, and measures 10 ft. 2 ins. wide by 6 ft. 7 ins. high. Masonry is used only where necessary, and in that case is so built as to form part of the lining of the tunnel when eventually completed. Concrete is put in to form a foundation for the side wall, and a water channel. The cross headings, connecting the two parallel headings, occur every 220 yds., and are placed at an angle of 56° to the axis of the tunnel, to avoid sharp curves in the contractors' railway lines. They will eventually be used as much as possible for refuges, chambers for storing the tools and equipment of the platelayers, and signal-cabins. The refuges, 6 ft. 7 ins. wide by 6 ft. 7 ins. high and 3 ft. 3 ins. deep, occur every 110 yds., every tenth being enlarged to 9 ft. 10 ins. wide by 9 ft. 10 ins. deep and 10 ft. 2 ins. high, still larger chambers being constructed at greater intervals.

Method of Excavation.—The work at each end of the tunnel is carried on quite independently, consequently, though similar in principle, the methods vary in detail, apart from the fact that different geological strata require different treatment. Broadly speaking, the two parallel headings, each 59 sq. ft. in section, are first driven by means of drilling machines and the use of dynamite, this work being carried on day and night, 7 days in the week; No. 1 heading is then enlarged to full size by hand-drilling and dynamite. On the Italian side, where the rock is hard and compact, break-ups are made at intervals of 50 yds., and a top gallery is driven in both directions, but, for ventilation reasons, is never allowed to get more than 4 yds. ahead of the break-up, which is gradually lengthened and widened to the required section. No timbering is required, except to facilitate the excavation and the construction of the side walls. Steel centers are employed for the arch; they entail fewer supports, give more room, and are capable of being used over again more frequently, without damage. They consist of two I-beams bent to a template and riveted together at the crown, resting at either side on scaffolding at intervals of 6 ft.; longitudinals, 12 ft. by 4 ins. by 4 ins., support the roof. Hand rock-drilling is carried out in the ordinary way, one man holding the tool and a second striking; measurements of excavation are taken every 2 or 3 yds., a plumb-line is suspended from the center of the roof, and at every half meter (20 ins.) of height horizontal measurements are taken to each side.

At the Brigue end a softer rock is encountered, necessitating at times heavy timbering in the heading, and especially in the final excavation to full size, Fig. 1. The bottom heading, 6 ft. 6 ins. high, is driven in the center, and the heading is then widened to the full extent and timbered; the concrete forming the water channel and the foundation for one side wall is put in; the side walls are built to a height of 6 ft. 6 ins., and the tunnel is fully

excavated to a further height of 6 ft. 6 ins. from the first staging. The side walls are then continued up for the second 6 ft. 6 ins., and from the second floor a third height of 6 ft. 6 ins. is excavated and timbered. Finally the crown is cleared out, heavy wooden centers are put in, the arch is turned and all timbers are withdrawn except the top poling boards, supporting the loose rock.

The masonry for the side walls is obtained either from the tunnel itself or from a neighboring quarry, and varies in character according to the pressure, but the face of the arch is always of cut or artificial stones, the latter being of 7 to 1 cement concrete. Where the alinement heading, or the "gallery of direction," joins the curving portion of tunnel No. 1, the section is very much greater, and necessitates special timbering.

Transport—Italian Side.—A small line of railway, 2 ft. 7½ ins. gage, with 40-lb. rails, enters all three portals, but since the construction of a wooden bridge over the Diveria, the route through the "gallery of direction," across heading No. 2, to tunnel No. 1, is used exclusively; this railway leads to the face in both headings, and, where convenient, from one heading to the other by the cross galleries. Different types of wagons are in use, but in general they are four-wheeled, non-tipping box wagons, supplied with brakes and holding 2 cu. yds. of debris. A special type of locomotive is used, designed to pass round curves of 50 ft. radius, and supplied with a specially large boiler to avoid firing in the tunnel.

Method of Working.—The drilling machines employed are of the Brandt type, Fig. 2, and are mounted in the following manner: A small four-wheeled carriage supports at its center a beam, the shorter arm of which carries the boring mechanism and the longer a counterpoise; near its center is the distributor. In the short arm is a clamp holding the rack-bar or butting column, which is a wrought-iron cylinder with a plunger constituting a ram, and is jammed by hydraulic pressure between the walls of the heading, thus forming a rigid support for the boring machine, and an efficient abutment against the reaction of the drill. This rack-bar can be rotated on its clamp in a plane parallel to the axis of the beam. Three or four separate boring-machines can be mounted on the rack-bar, and can be adjusted in any reasonable position.

The boring machine performs the double function of continually pressing the drill into the rock by means of a hollow ram (I) and of imparting to the drill and ram a uniform rotary motion. This rotary motion is given by a twin cylinder single-acting hydraulic motor (E), the two pistons, of 2⅝ ins. stroke, acting reciprocally as valves. The cranks are fixed at an angle of 90° to each other on the shaft, which carries a worm, gearing with a worm-wheel (Q) mounted upon the shell (R) of the hollow ram (I), and this shell in turn engages the ram by a long feather, leaving it free to slide axially to or from the face of the rock. The average speed of the motor is 150 revolutions to 200 revolutions per minute, the maximum speed being 300 revolutions per minute. The loss of power between the worm and wormwheel is only 15% at the most; the worm being of hardened steel and the wheel of gun-metal, the two surfaces in contact acquire a high degree of polish, resulting in little wearing or heating. Taking into consideration all other sources of loss, 70% of the total power is utilized. The pressure on the drill is exerted by a cylinder and hollow ram (I), which revolves about the differential piston (S), which is fixed to the envelope holding the shell (R). This envelope is rigidly connected to the bed-plate of the motor, and, by means of the vertical hinge and pin (T), is held by the clamp (V) embracing the rack-bar. When water is admitted to the space in front of the differential piston the ram carrying the drilling-tool is thrust forward, and when admitted to the annular space behind the piston, the ram recedes, withdrawing the tool from the blast-hole. The drill proper is a hollow tube of tough steel 2¾ ins. in external diameter, armed with three or four sharp and hardened teeth, and makes from five to ten revolutions per minute, according to the nature of the rock. When the ram has reached the end of its stroke of 2 ft. 2½ ins., the tool is quickly withdrawn from the hole and unscrewed from the ram; an extension rod is then screwed into the tool and into the ram, and the boring is continued, additional lengths being added as the tool grinds forward; each change of tool or rod takes about 15 secs. to 25 secs. to perform. The extension rods are forged steel tubes, fitted with four-threaded screws, and having the same external diameter as the drill. They are made in standard lengths of 2 ft. 8 ins., 1 ft. 10 ins., and 11¾ ins. The total weight of the drilling-machine is 264 lbs., and that of the rack-bar when full of water is 308 lbs. The exhaust-water from the two motor cylinders escapes through a tube in the center of the ram and along the bore of the extension-rods and drill, thereby scouring away the debris and keeping the drill cool; any superfluous water finds an exit through a hose below the motors and thence away down the heading. The distributor, already mentioned, supplies each boring-machine and the rack-bar with hydraulic pressure from the mains, with which connection is effected by means of flexible or articulated pipe connections, allowing freedom in all directions. The area of the piston for advancing the tool is 15½ sq. ins., which under a pressure of 1,470 lbs. per sq. in. gives a pressure of over 10 tons on the tool, while for withdrawing the tool 2½ tons is available. In the rock found at Iselle, namely, antigorio gneiss, a hole 2¾ ins. in diameter and 3 ft. 3 ins. in length is drilled, normally, in 12 mins. to 25 mins.; a daily rate of advance of 18 ft. to 19 ft. 6 ins. is made in a heading having a minimum cross-section of 59 sq. ft.; the time taken to drill ten to twelve holes, 4 ft. 7 ins. deep, is 2½ hrs.

When the debris resulting from one operation has been sufficiently cleared away, a steel flooring, which is provided near the face to enable shovelling to be more easily done and to give an even floor for the wheels of the drilling carriage, is laid bare at the head of the line of rails, and the drilling machines are brought up on their carriage by eight or ten men. When advanced sufficiently close to the face, the rack-bar is slewed round across the gallery and is wedged up against the rock sides; connection is made between the distributor and the hydraulic main, by means of the flexible pipe, and pressure is supplied by a small copper tube to the rack-bar ram, thereby rigidly holding the machine. Next, connections are made between the three drilling machines and the distributor,

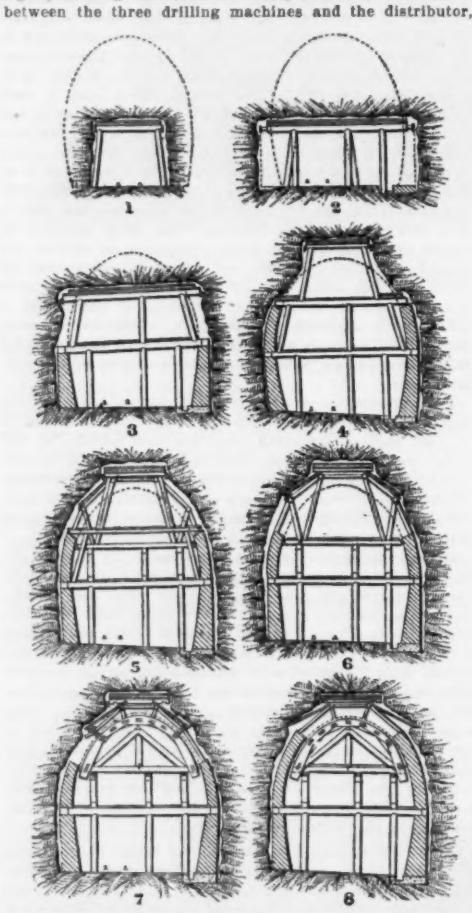


Fig. 1.—Cross-Sections of Simplon Tunnel, Showing Sequence of Excavation and Lining Construction.

and in 20 mins. from the time the machine was brought up all three drills are hard at work, water pouring from the holes.

The noise of the motors and grinding tools is sufficient to drown all but shouts, and where the extension rods do not fit tightly, small jets of water play in all directions, necessitating the wearing of tarpaulins by the men directing the tools. Lighting is done wholly by small oil-lamps, provided with a hook to facilitate fixing in any crack in the rock; electricity will probably be used to light that portion of the tunnel which is completed.

Two men are allotted to each drill, one to drive the motor, the other to direct and replenish the tool, one foreman and two men in reserve completing the gang. A small hammer is freely used to loosen the screw joints of the extension rods and drill. A hole is usually commenced by a two-edged flat-pointed tool, until a sufficient depth is reached to prevent the circular tool from wandering over the face of the rock, but in many instances the hole is commenced with a circular tool. The exhaust water during this period flows away by the hose underneath the motor. In the antigorio gneiss, ten to twelve holes are drilled for each attack, three or four in the center to a depth of 3 ft. 3 ins., the remainder, disposed round the outside of the face, having a depth of 4 ft. 7 ins. The average time taken to complete the holes is 1¾ hrs. to 2½ hrs. Instead of pulverizing the rock, as do the diamond drills, it is found that the rock is crushed, and that headway is gained somewhat in the manner of a circular saw through wood. The core of rock inside the tool breaks up into small pieces, and can be t[illegible] out if necessary when the drill requires lengthening.

The lowest holes, inclined downwards, are full [illegible] water; consequently two detonators and two fuses are inserted, but apart from this, water has little effect on the charge. The fuses of the central holes are brought together and cut off shorter than those of the outer holes, in order that they may explode first, to increase the effect of the outer charges. All portable objects such as drills, pipe connections, tools, etc., have meanwhile been carried back; the steel flooring is covered over with a layer of debris to prevent injury from falling rock, and to the end of the hydraulic main is screwed a brass plug pierced by five holes, and immediately the explosions occur a valve is opened in the tunnel and five jets of water play upon the rock, laying the dust and clearing the air. The necessity for this was shown on one occasion when the nozzle was broken by the explosion and the water had to be turned off immediately to avoid useless waste; on reaching the face, the atmosphere was found to be so highly charged with dust and smoke that it was impossible to distinguish the stones at the feet, although a lamp had been placed on the ground, and despite the fact that the air tube was in full blast, the men experienced great difficulty in breathing. A truck is now brought up, and four men clear a passage in front, through the heap of debris, two with picks and two with shovels, while on either side and behind are as many men as space will permit. The stone is thrown either to the sides of the heading or into the wagon, shovelling being greatly aided by the steel flooring, which, before the explosion, had been laid over the rails for nearly 10 yds. down the tunnel to receive the falling rock. These steel plates are taken up when cleared, and the wagon is pushed forward until the drilling machine can be brought up again, leaving the remaining debris at the sides to be handled at leisure during the next attack. The roof and side walls are, of course, carefully examined with the pick, to discover and detach any loose or hanging rock. The times taken for each portion of the attack in this particular antigorio gneiss are as follows: Bringing up and adjustment of drills, 20 mins.; drilling, between 1¾ hrs. and 2½ hrs.; charging and firing, 15 mins.; clearing away debris, 2 hrs.; or for one whole attack, between 4½ hrs. and 5½ hrs., resulting in an advance of 3 ft. 9 ins., or a daily advance of nearly 18 ft.

From this it appears that the time spent in clearing away the debris equals that taken up in drilling, and it is in this clearing that a saving of time is likely to be effected rather than in the process of drilling. Many schemes have been tried, such as a mechanical plough for making a passage; at Brigue, "marinage," or clearing by means of powerful high pressure water-jets, directed down the tunnel was tried, but the idea is not yet sufficiently developed.

Another series of experiments have been tried at Brigue with regard to the utilization of liquid air as an explosive agent instead of dynamite, and for this purpose a plant has been laid down, consisting of one ammonia-compressor, two air-compressors, and two refrigerators, furnishing 1-10 gallon of liquid air per hour at an expenditure of 17 HP. The system used is that of Professor Linde, who himself directs the experiments. The great difficulty experienced is that of shortening the interval of time that must elapse between the manufacture of the cartridge and its explosion. The liquid oxygen, with which the cartridge, containing kieselguhr (silicious earth) and paraffin, is saturated, evaporates very readily, losing power every moment; hence the effect of each cartridge cannot be guaranteed, and though it is an exceedingly powerful explosive when used immediately after manufacture, no practical result has yet been obtained.

Power Station.—Water is abundant at either end, and therefore hydraulic power is the motive force employed. On the Italian side, a dam 5 ft. high has been thrown across the Diveria at a point near the Swiss frontier about 3 miles above the site of the installations. A portion of the water thus held back enters, through regulating doors and gratings, a masonry channel leading to two parallel settling tanks, each 111 ft. by 16 ft., whence, after dropping all its sand and solid matter, the now pure water passes into the water-house, and, after flowing over a dam, through a grating, and past the admission doors, enters a metallic conduit of 3-ft. pipes. Each of the settling tanks and the approach canal are provided with doors at the lower end leading direct to the river, through which all the sand and solid matter deposited can be scoured naturally by allowing the river-water to rush freely through. For this purpose the floor of the basins is on an average gradient of 1 in 30. For a similar reason the river-bed just outside the entrance to the approach canal is lined with wooden planks, from which the stones collecting behind the dam can be scoured by allowing an iron flap, hinged at the bottom, to change its position from the vertical to the horizontal in a gap left purposely in the dam, so causing a rushing torrent to sweep it clean.

The chief levels are:

Level of water at dam	794.00	meters	above	sea	level.
" in water-house	793.70	"	"	"	"
" at turbines	618.50	"	"	"	"

giving a total fall of 175.20 ms. or 570 ft., and a pressure of 17.52 atmospheres.

The quantity of water capable of being taken from the Diveria in winter, when the rivers which are dependent upon the mountain snows for their supply are at their lowest, is calculated to be 352 gallons per second. Thus, taking the fall to be diminished by friction, etc., to 440 ft., and the useful effect at 70%, there is obtained 2,000 HP. on the turbine shaft.

The metallic conduit varies in material according to the pressure, thus cast-iron pipes 3 ft. in diameter and 13-16-in. thick are used up to a pressure of 2 atmospheres, from which point they are of wrought iron. The cast-iron portion has of late caused a good deal of trouble, owing to

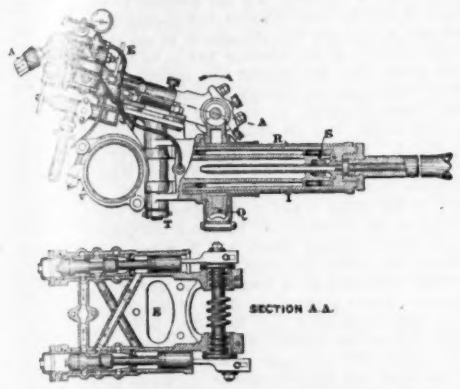


Fig. 2.—General Details of Brandt Hydraulic Rotary Drills Employed in the Simplon Tunnel.

settlement of the piers causing occasional bursts, consequently a masonry pier has been placed under each joint of this portion. The following table gives the thicknesses and diameters, varying with the pressure:

Water Pressure. Head in Feet.	Thickness. Millimeters.	Thickness. Inch.	Diameter Feet.	Diameter Inches.	Weight per Yard. Lbs.
246	6	¼	3	0	326
311	7	..	3	0	383
360	8	..	3	0	431
393	9	..	3	0	483
426	10	..	3	0	556
476	12	..	3	0	651
590	16	⅝	3	3½	977

This pipe is supported every 30 ft. on small masonry piers, on the top of which is placed a block of wood hollowed out to receive the pipe, thus allowing any movement due to the contraction and expansion of the conduit. However, to prevent this movement becoming excessive, the pipe is passed at intervals of 300 yds. to 500 yds. through a cubical block of masonry of 13 ft. side, strengthened by longitudinal tie-bars. Five bands of angle-bar riveted round the pipe, with their flanges embedded in the masonry, constitute a rigid fixed point. Straw mats are thrown over the pipe where it is exposed to the sun. The temperature of the conduit is not, however, found to vary greatly, since the pipe is kept full of water. To supply the rock-drills with water at a maximum pressure of 100 atmospheres, or 1,470 lbs. per sq. in., a plant of four pairs of high-pressure pumps has been laid down, and a still larger addition is in course of erection. At present, two Pelton turbines of 250 HP. each, running at 170 revolutions per minute, drive the pumps, by means of toothed gearing, at 63 revolutions per minute. These pumps are of very simple but strong construction, single suction and double delivery, entailing one suction and one delivery-valve, both heavy and both of small lift. The larger portion of the plunger has exactly double the cross-sectional area of the smaller portion, so that in the forward stroke half of the water taken in at the last admission is pumped into the high-pressure mains, and at the same time a fresh supply of water is sucked in. During the backward stroke half of this new supply is pumped into the mains, and the remainder enters the second chamber, to be pumped during the next forward stroke. Thus the work done in the two strokes is practically the same. The pumps are in pairs, and are set at an angle of 90°, to ensure uniform pressure and uniform delivery in the mains. Their size varies, but at Iselle there are three pairs, with a stroke of 2 ft. 2½ ins., and plungers of 2 11-16 ins. and 1⅞ ins. (approximately) in diameter, supplying 1.32 gallons per second.

To avoid injury to the valves, the water to be pumped is taken from a stream up the mountain side, and is passed through filter screens. The high-pressure water, after passing an accumulator, enters the tunnel in solid drawn wrought-iron tubes, 3⅛ ins. in internal diameter, 3-16-in. thick, and in lengths of 26 ft. The diameter of these mains varies with their length, so as to avoid loss of pressure. With the 1,250 yds. of tunnel now driven 10 atmospheres are lost.

At Brigue the installations are, as far as possible, identical. The Rhone water, however, before reaching the water-house is carried from the filter basins, a distance of 2 miles, in an armored canal built upon the Hennebique system,* the walls and supporting beams, of cement concrete, being strengthened by internal tie-bars of steel. The concrete struts, resembling balks of timber at a distance, are occasionally 35 ft. high and 1 ft. 7½ ins. square. The metallic conduit is 5 ft. in diameter, with a minimum flow of 176 cu. ft. per second and a total fall of 185 ft. In case water-power should be unavailable, three semi-portable steam-engines, two of 80 HP. and one of 60 HP., are always kept in readiness at each end of the tunnel, and are geared by belts to the turbine shaft.

*A net work of steel rods embedded in concrete.

Ventilation.—In tunnelling, one of the most important problems to be solved is that of ventilation, and it is for this reason that the Simplon Tunnel consists of two parallel headings with cross cuts at intervals of 220 yds. At Brigue, a shaft 164 ft. deep was sunk through the overlying rock until the "gallery of direction" was encountered. Up this chimney the foul air is drawn by wood fires, the fresh air—a volume of 19,000,000 cu. ft. per day, or 13,200 cu. ft. per minute—entering by heading No. 2, penetrating up to the last cross gallery, and returning by tunnel No. 1. The entrances of No. 1 and the "gallery of direction," besides those of all the intermediate cross galleries, are closed by doors. By this arrangement, however, fresh air does not reach the working faces, therefore a pipe, 8 ins. in diameter, is led from the fresh air in No. 2 to within 15 yds. of the face of each heading, and up this pipe a draft of air is induced by means of a jet of water, the volume to each face being 880 cu. ft. per minute. One single jet of water from the high-pressure mains, with a diameter of 1-16-in., is capable of supplying over 1,000 cu. ft. of air per minute at the end of 160 yds. of pipe, and during the attack the men at the drills are in a constant breeze with the thermometer standing at 70° F. At Iselle, air is blown into the entrance of heading No. 2 at the rate of 14,100 cu. ft. per minute by two fans driven from the turbine shaft. This air travels from the fans along a pipe, 18 ins. in diameter, till a point 15 yds. up the tunnel is reached, where beyond a door the pipe narrows to form a nozzle 10 ins. in diameter. This door is kept open to allow the outside air to be induced up the tunnel, as the headings are at present only 2,500 yds. long, giving a resistance of not quite sufficient power to cause the air to return. The fresh air then travels up No. 2, crossing over the top of the "gallery of direction," from which it is shut off by doors, to the last cross gallery, returning by No. 1, and finally leaving either by the "gallery of direction" or by No. 1. A system of cooling the air and driving it on by means of a large number of water-jets will be installed in No. 2 where that heading crosses over the "gallery of direction," but at present there is no need for it.

The average temperature at the face is 73° F. during the drilling operation, 76° F. after firing the charges, and a maximum of 80° F., lately attaining to 86° F. on the south side, with 80° F. and 85° F. before and after firing. The temperature of the rock is taken at every 110 yds. in holes 5 ft. deep, and shows a gradual increase according to the depth of overlaying rock, to the conductivity of the rock, and to the form of the mountain surface. The maximum hitherto reached on the north side is 68° F., while on the south side, although a smaller distance has been traversed, it attains to 79° F., due to the more rapid increase in depth. Moreover, the temperature of the rock is observed at the permanent stations, 550 yds. from the entrances, in its relation to that of the tunnel and outside air, and though on the north side that of the rock varies almost as quickly as that of the tunnel air, on the south it is influenced very much less.

A few statistics may be of interest with regard to the progress of the last three months (taken from the trimestrial report of January, 1900). At Brigue, where there are three drilling machines in No. 1 and two in the parallel heading, the total length excavated was 995 yds. or 6,409 cu. yds. in 89 working days, the average cross-sectional area being 57 sq. ft. This required 597 attacks and 3,066 holes, which had a total depth of 26,600 ft., and 14,700 re-sharpenings of the drilling tool, with 44,000 lbs. of dynamite.

The average time occupied in drilling was 2 hrs. 45 mins., while charging, firing, and clearing away the debris took 6 hrs. 35 mins. At Brigue 648 men and 29 horses were employed at one time in the tunnel. At Iselle the numbers were 496 men and 16 horses, working in shifts of 8 hrs. Outside the tunnel, in the shops, forges, etc., the men work 8 hrs. to 11 hrs. per day, the total being 541 men at Brigue and 346 men at Iselle. On the Italian side, where the rock is very much harder, there were three drilling machines in each heading; the total length excavated, with a cross-sectional area of 62 sq. ft., was 960 yds. or 6,700 cu. yds. in 91 working days. This required 61,293 re-sharpened tools, 758 attacks, 7,940 holes with a total depth of 33,000 ft., and 56,000 lbs. of dynamite. The average time spent in drilling was 2 hrs. 55 mins., and in charging and clearing 2 hrs. 36 mins. Thus, in the hard gneiss, to excavate 1 cu. yd. of rock required 8½ lbs. of dynamite, and each tool pierced 6½ ins. of rock before it required re-sharpening.

Up to January 1, 1900, the total length of heading on the north side was 2,515 yds., and on the south side 1,720 yds., or a total of 4,235 yds. out of 21,575 yds., the full length of the tunnel. Allowing for unavoidable and unforeseen occurrences, such as strikes, war, etc., the contractors expect to complete tunnel No. 1 and the parallel heading by May, 1904.

THE MARLBOROUGH BROOK FILTER BEDS; METROPOLITAN WATER SUPPLY FOR BOSTON AND VICINITY.

Among the various measures inaugurated by the city of Boston for the protection and improvement of the character of its water supply in years gone by, was the removal of sewage from its drainage area through the action of several towns, Boston contributing to the expense of the sewage purification works thus made necessary. Later on, the city built filter beds for the treatment of the water of some small streams subject to surface pollution and possible surreptitious pollution of a worse character. This line of work has been carried on by the Metropolitan Water Board, to which body all the works pertaining to the Boston water supply, except the distribution system, have been turned over. The various improvements in question, under both the old and new regime, have been carried out under the direction of Mr. Desmond FitzGerald, Past-Prest. M. Am. Soc. C. E., now Engineer of the Sudbury Department of the Metropolitan Water Supply. As is well known, Mr. F. P. Stearns, M. Am. Soc. C. E., is Chief Engineer to the Board. The report for the year 1899 contains the following description of some filter beds built by the board last year:

The plans for these filter beds were completed early in the year, and the contract for their construction was awarded to Auguste Saucier on May 16.

The city of Marlborough is situated quite near to the Sudbury reservoir and on its northerly side. A system of sewerage was introduced into the city a number of years ago, and the sewage removed to filter beds located outside of the watershed from which the water supply is taken. A rigid system of inspection was inaugurated by the city of Boston and has been maintained by the Metropolitan Water Board; but, notwithstanding these efforts to keep the water of the brook in good condition, it is at times of very bad quality, as it receives the washings of the streets.

The Marlborough Brook filter beds were designed to filter the water of Marlborough Brook before allowing it to pass into the Sudbury Reservoir, and are so situated that the water will flow upon them by gravity. The beds are of sufficient capacity to filter a very large run-off from the watershed tributary to the brook; this watershed has an area of about 1.8 square miles.

A small settling reservoir was built in 1898 on the line of the brook below the city of Marlborough and immediately above the site for the filter beds; here heavy matters are allowed to deposit before the water is turned upon the beds. Below the settling reservoir is an open channel about a half-mile in length, skirting the beds at a higher level, which serves to distribute the water to subsidiary channels.

The filter beds are separated into two divisions, the first consisting of 17 artificial beds and the second of 8 natural beds. Between the two groups is a storage bed having an area of 1.22 acres.

The total area of the artificial beds is 5.36 acres, the largest covering an area of 0.7 of an acre, and the smallest an area of 0.07 of an acre; the average size being 0.33 of an acre. On the line of the main distributing channel there are two dams, by means of which the whole flow of the brook may be distributed to the artificial or natural beds, as desired. From the main channel there are four subsidiary channels, which distribute the water to the different beds. These channels are provided with concrete dams and inlets to the beds. The inlets for both the artificial and natural beds are of the same general form. They consist of a concrete wall with an opening 3 ft. wide in the middle, controlled by stop-planks.

The artificial beds are filled with a thickness of 24 ins. of sand, supported upon several layers of graded materials and screened gravel stones and underdrained by vitrified pipes. The beds are surrounded by embankments 2 ft. in height. The flow is controlled in outlet wells furnished with movable weirs.

The area of the natural beds is 8.63 acres, each bed having an area of about one acre. The site of these beds was originally occupied by gravel knolls, the upper portions of which were removed to furnish material for the filling of the artificial beds. This material contained so much loam and other fine material that the larger part of it had to be washed before being placed. After the upper material was removed the natural beds were formed by surrounding the excavated areas with low embankments. The filtered water from the natural beds is collected by pipes surrounding the beds and laid with filter joints; but there are no underdrains beneath the beds as in the artificial system. The work under this contract was substantially completed Dec. 16.

During the severe drought of the past season the contractor used all the water of the brook for washing the sand for the artificial beds, and the effluent was afterwards filtered through the ground before reaching the reservoir. On the few occasions when there was a surplus of water it was filtered through such beds as were completed, so that

the water of the brook has not been allowed to pass unfiltered into the Sudbury reservoir since June.

The following table shows the quantity of work done and the cost of construction of these filter beds:

Earth excavation	104,837 cu. yds.	$29,221
Rock excavation	23 " "	12
Portland cement concrete masonry.	636 " "	4,453
Masonry:		
Brick, in Port. cem't mortar...	30 " "	426
Dimension stone	11 " "	316
First-class stone paving	52 " "	182
Second-class stone paving	121 " "	182
Vitrified pipe:		
6 to 15-in.; open joints	4,367 lin. ft..	1,495
6 " 24-in.; cement joints	2,172 " "	1,329
10 " 20-in.; filter joints	3,799 " "	2,356
Day-labor work provided for in contract		2,414
Total		$42,386

HIGHWAY GRADE CROSSING ALARMS.*

By J. S. Evans.†

A few years ago automatic crossing alarms were practically an unknown quantity, because the few that were then in use gave such poor service that their general adoption could not be recommended. But as railroading has advanced so have crossing alarms, with the result that there are now quite a number on the market giving excellent satisfaction. The matter of protecting highway crossings by means of automatic alarms commands attention for the following reasons: First, the number of accidents that are constantly occurring and the accompanying loss of human life and expense incident thereto. Second, measures are necessary to forestall unjust legislation against railways. Local, city and town authorities, in their zest for creating positions for political favorites, often saddle heavy expense upon railways. Third, the increased speed and number of trains which demand a clear right of way. From the above it is evident that more and better protection is necessary at all highway crossings in thickly settled districts and many dangerous crossings in sparsely settled districts, which cannot be furnished, except at prohibitory expense, unless it can be done by some automatic device.

The protection of highway crossings with a gate and gateman means, approximately:

An initial investment of	$300.00
Maintenance expense (labor, interest, repair, fuel, etc.), per annum	400.00
	$700.00
Cost of protection, first year	$700.00
Cost of protection per annum thereafter	400.00

To guard a crossing with an automatic alarm costs, approximately:

An initial investment of	$200.00
Maintenance expense, per year	50.00
	$250.00
Cost of protection, first year	$250.00
Cost of protection per annum thereafter	50.00

These figures show a net saving of at least $350 per year in favor of the automatic alarm, not taking into consideration that the alarm is on duty all the time, 24 hrs. a day and 365 days of the year.

The questions now arise: Are automatic alarms an adequate protection? What is the proper principle upon which they should be constructed? What may be expected of them? The signal engineers of all the larger roads have long since condemned any electric signals that the elements or train movements might injure or put out of order without notice thereof being given immediately. Hence, the closed track-circuit has been universally adopted because of its simplicity, reliability and self-operating tell-tale qualities when properly constructed.

Nearly all track-circuit crossing bells operate on substantially the same principle, and if properly installed and maintained will announce the approach of every train. Such a signal should be designed to meet the following requirements: The alarm at the crossing should be given when the first pair of wheels reaches a point sufficiently distant from the crossing to give at least 20 seconds warning for the fastest approaching train. It should not cease until the last pair of wheels has crossed the highway. If the alarm is silenced when the first pair of trucks has passed the highway, a second approaching train would give no warning, and such a condition where double tracks are used would increase the danger instead of eliminating it.

I may say here that the road with which I am connected has a crossing protected where there are four tracks, all of them used for single track movements, and it happens very frequently that a second and even a third train approaches the crossing at a high rate of speed before the first has entirely passed the highway. If the bell should stop ringing when the first pair of wheels reached the highway, a person waiting to pass over would proceed when the first train had passed, perhaps just in time to be met and injured by the second train on one of the other tracks. The alarm not being silenced, however, until the last wheel approaching from any direction has reached and passed the highway, the warning continues and danger of accident is averted. It often happens that a train of considerable length is followed by a light engine, only a few hundred feet distant from the rear end of the train. This is especially the case where trains are coming into the yard limits. In such a case it is very evident that if the first pair of wheels silenced the bell there would be no warning of the approach of the second train. Again, it is not a rare occurrence for a train to break in two while running and the forward section of the train may run a considerable distance ahead of the remaining portion. In this case if the bell were silenced by the first pair of wheels, the rear end of the train approaching the crossing would be as much a menace to human life as the light engine or second train. Incidents of this kind are not lacking to demonstrate the value of the above feature.

An alarm should be constructed on the closed-circuit principle, so that, if the batteries have become exhausted, either by actual work or by accident, an indication thereof will be given. The breaking of relays, wires, or other mechanisms forming a part of a highway alarm should also be automatically indicated. The bell should be sufficiently loud and of such a decided, plain stroke that its meaning cannot be misunderstood. The batteries should be placed in receptacles in which they will not freeze, and in which they cannot be tampered with (preferably iron boxes), or non-freezable batteries should be used. The mechanism of the alarm should be as simple as possible, with only as many moving parts and contacts as are absolutely necessary, so that the ordinary lineman or telegraph operator who is familiar with simple electrical devices will have no trouble in understanding it, and will be able to install and maintain it.

Lastly, under no circumstances should the bell ring after the train has gone by the crossing, or ring when actual danger at the crossing does not exist. If there are sidings or passing tracks at the crossing, the alarm should be sounded for all tracks; but it should be so arranged that a train taking the passing siding and stopping before it reaches the crossing will not operate the bell continuously, but as soon as the train starts forward again (at which time danger will exist at the crossing) the bell should ring just the same as if it were a through train on any of the other tracks. While the bell is inoperative for a train so standing on a passing siding, the bell must give warning for all approaching trains on the other tracks; and should this train back away from the crossing instead of proceeding no alarm must be given for this movement. In other words, any crossing alarm should be so arranged and designed that there can be no mistaking what it means when the gong is sounding; that is, for every wheel that approaches the crossing which is a menace to human life it must cause that alarm to be given, but under no circumstances must it give a false alarm. In all track circuits, whenever they are short circuited, no matter whether the wheel is going away from or approaching the crossing, the alarm will be sounded. Ample provision should be made to guard against the sounding of the alarm as the wheel goes away from the crossing, and any alarm which cannot be so arranged as to cover this point is, in my estimation, not a proper one to ask the public to depend upon, and would not furnish adequate defense to a railroad company so using it, in case of accident.

*A paper read before the Association of Railroad Telegraph Superintendents.

†Superintendent of Telegraphs, New York, Chicago & St. Louis R. R.

ENGLISH PRACTICE IN CLEANING WATER MAINS WITH SCRAPERS AND BRUSHES.

Much valuable information on the cleaning of water pipes was brought out before a recent meeting of the Institution of Mechanical Engineers, in London, an interesting discussion following the reading of a paper by Mr. William Ingham, Borough Water Engineer of Torquay, on the experience of that place. We give below quite a full abstract of Mr. Ingham's paper, with some account of the discussion, including in the latter, more particularly, remarks by Mr. Geo. F. Deacon, of Liverpool, supplemented by later information supplied by Mr. Deacon to one of our London contemporaries*:

Our abstract of Mr. Ingham's paper is as follows:

The Incrustation of Iron Pipes at the Torquay Water-Works.

The water supply of Torquay, Newton Abbot, St. Mary Church, and Cockinton, is obtained from a tributary of the River Teign, which rises in the granite hills on a western spur of Dartmoor. Two storage reservoirs, containing 360,000,000 (U. S.) gallons have been constructed there, and the water is conveyed by two cast-iron mains to Torquay; the old main laid in 1858 is 14 miles in length, and was first scraped in 1866. It is 10 ins in diameter as far as Newton Abbot, and 9 ins. forward to the foot of Chapel Hill, where it is reduced again to 8 ins. between that point and the service reservoir. This main was not coated with any protective material, and within twelve months of being laid began to show signs of corrosion. Dr. Angus Smith's coating was unknown at the time the pipes were laid, and no one thought that the water from the Dartmoor hills would cause such a rusting and deleterious action on the pipes. It was, therefore, with considerable surprise that at the end of eight years the delivering power of the mains should be reduced to 51% of their full discharging capacity. A report was submitted by the engineer, and the question of taking up the pipes in quarter-mile sections and coating them was considered, but as this was thought to be too expensive some other way out of the difficulty had to be found. It was at this period that Mr. Appold was consulted, and the idea of sending a scraper through the main was first suggested, and, being accepted, he received instructions to have a scraper made. The outcome of this was the scraper shown in Fig. 1. The subsequent improvements (Figs. 2 and 3) were due to Mr. Box and Mr. William Froude, and the scrapers have not been altered since 1873. The scraper now in use (Figs. 3 and 4) was described and fully illustrated by Mr. Little at the Penzance meeting.*

The 10-in. scraper, which is 3 ft. 8 ins. in length, consists of two parts, the front portion being the knives and springs supported by a frame-work, and the rear of two pistons. These pistons are made of brass, and are about 1 in. less in diameter than the pipe. Immediately behind these pistons are leather discs strengthened by segmental iron plates; they are made rather larger than the diameter of the pipe, and the pressure of the water acting on them propels the machine forward. The rear part of the scraper is connected to the front by a swivel joint, which has a considerable amount of play so as to pass round curves easily. Just in front of the joint there is a cylindrical guard formed of flexible steel segments, which protects the piston leathers. The steel knives are four in number, and are kept in position by steel springs. From the nose of the scraper four pieces of steel project backwards, which serve to keep the scraper concentric with the pipe. The knives press outwards against the inside of the pipe with a force of about 48 lbs., and having a backward as well as a radial motion they give way on meeting a projection, which causes a pressure on the point of the knife of 60 lbs. The knives are rather more than one-fourth of the circumference in length, and are in pairs diametrically opposite to one another, one pair being about 4½ ins. in advance of the other; they are V-shaped, and the scraper moves bodily round if they meet with a ferrule or anything of that kind. The two pistons already referred to are placed at such a distance apart that they will cover the largest hole of any branch pipe from the main, otherwise the water would rush past the pistons and cause the scraper to stop. The force required to drive a 10-in. scraper at Torquay is from 350 to 400 lbs., or about 5 lbs. per sq. in., but for the smaller scrapers the pressure required would be much more because the area of a small pipe compared with the circumference is much less than in the larger sizes.

At the Torquay water-works the scraper is inserted where the head due to water is only 3 ft., but when the wash-out pipe in front is opened a partial vacuum is created, and the actual head is then 3 ft. plus the difference between the atmospheric pressure and the pipe pressure in front of the scraper. Where scraping is necessary it is not advisable to have the radii of curves in the pipe line under 30 ft., although in well-proportioned scrapers 15 times the diameter of the pipe will be sufficient. For pipes under 5 ins. diameter water-pressure scrapers cause considerable trouble and do not act very well. In laying pipes which will eventually require scraping, it is recommended that the pipe jointing be carefully watched to see that no lead finds its way into the pipe. Stones, chisels, and rubbish of all kinds are taken from newly-scraped mains, and cause considerable annoyance and trouble before the wash-out or hatch-box is reached. Before scraping is commenced, pipes and double collars should be placed alongside the main, in case the scraper sticks and the pipe has to be cut out; cutting tools, spades, picks, lead, yarn, fire-basket, hand-pump, and a full complement of pipe-laying tools should accompany the men when scraping. The approximate cost of scrapers, hatch-boxes, and wash-outs (each) may be taken as follows:

	10-in.	6-in.	4-in.
Scrapers complete	$112	$49	$9
Hatch-boxes	31	19	10
Wash-outs	24	17	12

A 6-in. wash-out will be quite sufficient for a 10-in. main, a 4-in. for a 6-in., and a 3-in. for a 4-in. The 4-in. scraper would be of the Kennedy pattern. (See Engineering News, Aug. 2, 1894.) It is difficult to give the price of scraping any main without knowing the full particulars of the pipe line, but the accompanying list taken from Mr. Barr's paper read before the Institution of Engineers and Shipbuilders in Scotland, March, 1897, on the "Scraping of Water-Mains," will be of interest.†

*Mr. Ingham's paper is printed in full, and the discussion is reported, in both "Engineering" and "The Engineer" of Nov. 3. We are indebted to the former for the originals from which our illustration of the Torquay scrapers have been prepared, and the latter (issue of Nov. 17) for the details of the brush used by Mr. Deacon at Liverpool.

In our issues of July 20 and 27, 1899, we described scrapers used at St. John, N. B., and Boston, Mass., and gave a bibliography of the subject.

*Proc. Inst. Mech. Engrs., 1873, p. 216.

†The bulk of the figures in the table (including those from 1877 to 1891), expressed in American equivalents, were given in Eng. News, Aug. 2, 1894.—Ed.

The first scraping will be found more difficult than the subsequent ones, and, once commenced, the pipes require scraping afterwards at short intervals. At Torquay this is done to both trunk mains every year, and the delivery is increased about 28% even after such a short period. As a rule seven men take part in the scraping at Torquay, and these are placed 20 or 30 yds. ahead of one another, and run along as the machine progresses. The reason of so many men being required is owing to the variations in the speed of the scraper, for if it rushes past any one or two of them, the next man ahead locates it. If the scraper is lost there is considerable trouble in finding it again. So it pays to have a few extra men about to avoid losing time, and, moreover, if the scraper sticks they are required to excavate and cut out the pipe. If the scraper stops it is usual to open the last wash-out and then shut it quickly; the impetus thus obtained often carries it past the impediment, but care should be exercised to see that the reaction is not too great to force the pipe joints or to burst the pipes; should this be unsuccessful a wisp of hay must be inserted, which makes practically a water-tight piston, and thus increases the pressure on the scraper. If this fails, then tapping the main with a hammer where the scraper has stuck often causes its release. When the above methods have been tried and end in failure, the only course is to cut out the pipe. If it is desired, the scraper can be examined at any hatch-box by inserting an iron cup to catch it.

A section of the old main from Tottiford intake to Torquay is shown on the diagram (omitted.—Ed.). The depth of the pipe underground is about 3 ft., except for a distance of about 180 ft., where it increases to 18 ft. at the deepest point. The difference in head between the intake at Tottiford and the lower or Chapel Hill service reservoir is 468 ft., and the average gradient 1 in 157. The first hatch-box is placed at Knowles Hill about eight miles from the intake and the second one at the foot of Chapel Hill, at Torquay, nearly six miles further on. Wash-outs are placed at the bottom of all valleys, and the speed of the scraper can be regulated by opening or shutting down the valve. The scraper moves quicker when on a down grade than it does on an up grade, and this is due to the weight (132 lbs.) of the scraper. Air-valves are placed on most of the elevations, and it may be of interest to know that these have a considerable effect on the speed of the scraper; these ought to be shut off when the scraping is in hand because the air rushes in when the water is withdrawn from the pipe, and instead of a partial vacuum we get the atmospheric pressure against the scraper. These air-valves were fixed in 1897, and since then the amount of corrosion has decreased somewhat; this is probably due to the gases escaping instead of being carried along by the water.

The cost of scraping the old main is about 0.1d. per lin. yd. (or $3.50 per mile for labor only, on 9 and 10-in. pipe.—Ed.). This is a very low figure, and is perhaps the cheapest piece of scraping in the country. The men engaged are thoroughly in touch with the work, and no difficulty is experienced in following the scraper at any part of the line, except for about 180 ft., where the pipe is about 18 ft. below the surface of the ground. The scraping is done during the day, but where the line passes through Newton Abbot operations are commenced early in the morning, before much traffic is on the road. It is very exciting to follow the scraper over hill and dale, and especially so if the wash-out pipe in front has been fully opened. A speed of 7½ miles per hour can be obtained for about ¾-mile on one part of the line.

The theoretical delivery of the old main is 595 (Imp.) galls. per min., according to Box, and is calculated by the formula:

$$G = \left\{ \frac{(3 \times D)^5 \times H}{L} \right\}^{\frac{1}{2}}.$$

Prony's formula:

$$G = \left[\left\{ \left(16.333 \times \frac{H \times d}{L} \times 0.00665 \right)^{\frac{1}{2}} - 0.0816 \right\} \times d^2 \times 2.04. \right]$$

gives 616 (Imp.) galls. per min. Eight years after the pipes were laid the delivery was only 317 (Imp.) galls., or 51% of Prony's delivery, the head lost being about 351 ft. The present delivery after scraping is 708 (Imp.) galls. per min., or 92 galls. more than given by Prony's formula. This increase can only be accounted for by the corrosion of the main itself, and as the delivering power of a main varies as the 2.5 power of the diameter when head and length are constant, the main must have been enlarged from 10 to 10½ ins. diameter in 41 years. After 12 months it is found that the nodules are about ⅛-in. to 3-16-in. in height, but the effect is such that the 10-in. pipe has only a delivering capacity of a 9-in. one. This is due to the eddies developed in the water by the nodules, and also to the much larger surface exposed to friction. For instance, taking a pipe 10 ins. in diameter, which is covered with nodules the surface exposed to friction would be approximately 35 ins., whereas the circumference of the pipe would only be 31.4 ins., the increase being about 11%. Working out the cubic contents of the nodules, it is found that 24 cu. ins. of rust is formed per lin. ft. of pipe, and as the length of the main is 24,352 yds., we get 1,014 cu. ft. of nodules. Now, as the nodule contains 49.03% by weight of iron, and 1 cu. ft. of the incrustation weighs 93 lbs., the total loss of iron in the whole length of the main is no less than 21 (long) tons per annum. This can be checked by taking the area of the inside of the main and multiplying it by ¼-in., which is the thickness of the iron lost by corrosion in 41 years; this calculation gives 20.5 (long) tons for one year, and compares very favorably with the first one, being only about 2½% lower. If before the scraping is commenced a pressure gage is fixed at different points in the pipe line and the pressure plotted on a section, the condition of the pipe can be arrived at by comparing it with the theoretical hydraulic gradient of the pipe. The points on the section will show certain dips below the theoretical gradient owing to the greater loss of head due to friction. If the dip is gradual it shows that the rusting is even throughout, but if the line rises and falls the rusting will be worse where the dip is largest and smallest where it is least. Special obstructions, such as a badly-run joint or a heap of stones, would only show the dip at that point, and would recover itself immediately after passing it.

During the summer of 1896 it was found necessary to scrape the new 10-in. main (which was coated with Dr. Angus Smith's composition) for the first time, and the deliveries into the Warberry reservoir before and after the scraping were 516 and 663 (Imp.) galls. per min. respectively, giving an increase of 28.5%. For scraping purposes this main is divided into two lengths similar to the old main. It was laid in sections as required, having been commenced in 1877 and completed in 1891. The difference in head between the intake at Tottiford and the Warberry service reservoir is 306 ft., and gives a hydraulic gradient of 1 in 264. During the scraping operations the scraper safely got through, but on arrival at the first hatch-box—eight miles from where is was inserted—it was found to be broken and badly strained. When, however, it is mentioned that 35 lbs. of joint lead, some yarn, and a bucketful of stones were in front of it, it is surprising that the scraper came through at all. The rear piston disc, two knives, one spiral and one longitudinal spring were broken, and it cost $50 to repair the damage before the second length of piping could be scraped. The actual time taken to scrape the 14 miles of pipe was three hours for the first eight miles and three hours for the second section of six miles, or an average of 2⅓ miles per hour. There are seven scour-out valves on the eight-mile section and seven on the six-mile. These are left open after the scraper has passed until the water becomes clean, and it is here that the time is lost, for in some cases this takes 20 minutes. A margin of time also has to be left between the opening of the next scour-out and the one which has been reached, as the leading men cannot be seen on any part of the line. It is found that the greater the velocity of the water passing through the pipes, the greater is the corrosion and incrustation so long as scouring action is avoided. In the Torquay mains the velocity of the water is rather high, being 3½ ft. per sec. in the 10-in. length of the old main, and 4.32 ft. per sec. in the 9-in. portion, while in the new main it is 4 ft. per sec. The analysis of a sample of rust taken from the Torquay main in May is appended, along with two other analyses from the water-mains of Aberdeen.

The percentage of iron in the rust is 49.03%, leaving 50.97% for matter that has been deposited. This latter amount is composed of lime, organic matter, silica, carbonic acid, etc., so it is easy to trace where the different constituents were obtained for building up the nodules. A portion of the carbon, sulphur, and silicon is no doubt obtained from the cast iron of the pipe, whilst the other portion is extracted from the solid matters carried in the water. The nodules of rust are made up of a series of layers, and these appear to increase in hardness the further they are from the center. The center portion of the nodule is generally made up soft material, and when dry goes to a fine powder. The fact of there being a series of layers suggests that they are built up periodically like the rings in the harder kinds of timber. This may be due to

Analyses of Rust taken from the Torquay Mains Compared with that of Aberdeen.

	Aberdeen 4-in. uncoated pipe.* %	Aberdeen 10-in. coated pipe.† %	Torquay 10″ uncoated pipe.‡ %
Volatile or combustible mat'r	16.62	18.05	.....
Sulphuric anhydride	0.60	1.08	1.44
Phosphoric anhydride	Trace.	Trace.	....
Magnetic oxide of iron	32.47	0.36	....
Iron oxide	9.04	37.55	70.05 Fe_2O_3
Insoluble sandy matter	41.27	42.78	.....
Lime	Trace.	0.18	0.37 CaO
Moisture	....	....	13.60
Water and organic matter	....	....	11.36
Magnesia	....	....	Trace. MgO
Silica	....	....	1.09 SiO_2
Combined chlorine	....	....	Trace.
Sulphuric acid	....	....	1.44 SO_3
Carbonic acid	....	....	2.12 CO_2

*21 years in use. †15 years in use. ‡41 years in use; rust only one year old.

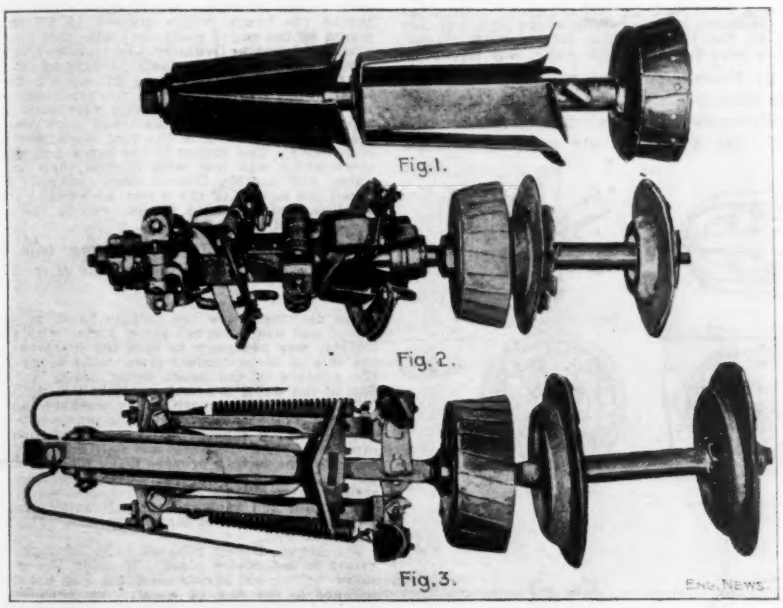
the variations of heat, magnetism, greater acidity of water at one time than another, or some organic impurity in the water. The oxygen extracted from the water must we know pass through the outer layers before it reaches the iron of the pipe, and the outer layer is always less oxidized than the inner; whenever a nodule is cut off the pipe immediately after the water has been drawn off, this top layer will be found of a dark color, whilst the inside will be the well-known brownish-red color of iron rust. As soon, however, as the nodule has been taken away from the water and begins to dry, this dark layer changes by oxidation into the brownish-red color of the interior. The chemical action in the formation of rust is as follows. The iron is first attacked by the carbonic acid and water, and this forms ferrous carbonate thus:

$$Fe_2 + 2\ CO_2 + 2\ H_2O = 2\ FeCO_3 + 2\ H_2. \quad (1)$$

The ferrous carbonate is then dissolved by the excess of carbonic acid in the same manner, as the $CaCo_3$ is held in solution by chalk water. Ferrous carbonate, being a very unstable compound, is quickly oxidized by the oxygen in the water, and forms ferric oxide (Fe_2O_3) and carbonic acid gas thus:

$$2\ FeCO_3 + O = Fe_2O_3 + 2\ CO_2. \quad (2)$$

It will therefore be seen that a similar amount of carbonic acid gas is given off in No. 2 as is used in No. 1; so it follows that a small quanity of carbonic acid suffices to keep up the reaction. Ferric oxide is not magnetic, but ferrous carbonate is, and no doubt this magnetism plays a very important part in the rusting of water-pipes. The incrusation or deposit varies considerably in different districts. At Southampton, where the deposit is derived from wells sunk in the chalk, the coating is of pure calcium carbonate, which is very pretty to look at, and forms a desirable interior surface from one point of view, if not from the other of reduction of pipe area.



FIGS. 1-3.—VIEWS SHOWING DEVELOPMENT OF WATER-PIPE SCRAPERS AT TORQUAY.

At Brighton, with water from the wells in the upper chalk, there is very little deposit or rust, while at Leicester, where it is obtained from an upland gathering ground of slate rocks and red marls, they are compelled to scrape the mains. At Nelson and Burnley the water is from the millstone grits, and both are upland supplies; in these cases the mains require scraping, and in the first case an accumulation of 13 years' rust reduced the delivery of a trunk main from 1,120,000 to 811,000 (Imp.) gallons per day. At Stroud, with well water from the Mitford sands and blue lias, they are troubled with a deposit of lime. Where well waters are derived from the old red sandstone formation they are not as a rule troubled much with either incrusation or deposit, but water from the greensand causes rust in some cases.

Speaking generally, it may be laid down with a fair approximation to the truth that well waters have not as great an action on pipes as those from upland gathering grounds, but where the water is soft the corrosive action will be greater. Filtered water has also a less corrosive power than unfiltered water. The liability of cast iron, wrought iron, and steel to oxidize is as follows: Cast iron, 100; wrought iron, 129; steel, 133. Engineers who have to deal with soft upland water supplies should take these figures into careful consideration when designing their pipe lines. Whatever protective covering is applied to pipes, soft waters will cause rusting within a few years of being laid. At Torquay six years is the outside limit when this commences, so every precaution is taken to see that the pipes are well coated. The alkalies, alkaline carbonates, and ammonia have a slight dissolvent action on Dr. Angus Smith's composition, and the Torquay water is slightly alkaline at times, whilst at others it is slightly of an acid character, probably due to peat. At the same time there is always a small amount of free ammonia present, and probably that is the reason of coated pipes rusting within such a comparatively short period. In some pipe foundries it is to be regretted that those in charge do not study this subject of rusting sufficiently, and therefore fall into the error of supposing that a little preliminary rusting before the dipping take place does not matter. For water from granite districts, especially the plates are riveted up, and then dipped in nearly boiling asphaltic composition. The composition should be natural asphalt, containing a large proportion of bitumen, with just sufficient creosote oil added to make what is necessary to produce when cold a smooth plastic and strongly adhesive varnish. Much has been done to get a satisfactory coating to pipes, but there is still considerable room for improvement, and it is hardly necessary to point out that a fortune awaits the man who can invent something that will withstand the action of soft waters.

In the discussion which followed the paper, Mr. H. M. Brunel referred to the early history of the incrustation at Torquay, and referred to two papers on the subject, as follows:

* * * * * it was the incrustation of the original Torquay main which had led to a revision of our theories of the nature of hydraulic resistances. In 1869 Mr. Edmund Froude read a paper at the Exeter meeting of the British Association dealing with this matter. His father, Mr. W. Froude, had been called in by the council at the outset, and by means of pressure gages and levels, had ascertained the actual facts of the case. These proved that the defect was an unusual one, and did not arise merely from a reduction in the diameter of the pipe. As a remedy Mr. Appold suggested the scraper, and this was tried on a short length, and the immediate benefit was so obvious that the local board gave instructions for applying the system to the whole main. Mr. Box, Mr. Froude, and others, all had a hand in devising these scrapers, the work being executed at the works of Messrs. Easton and Amos. In Mr. Edmund Froude's paper, above referred to, the defect was attributed to the internal corrosion of the pipe. The diminution in diameter did not, however, exceed one-eighth, and if, according to the then received view, the water simply filled up the roughnesses, making a smooth bed for the main flow, this decrease of diameter was quite insufficient to account for the falling off in the discharge, and hence it was suggested that the defect was really due to the increased roughness of the surface. A subsequent paper by Mr. William Froude on the difficulties of the then received views was also worthy of attention. In this Mr. Froude pointed out that the incrustation caused the defect in the capacity of the pipe, and that the old opinion, that the roughness did not much matter, as the cavities were filled with still water, was erroneous.

Mr. G. F. Deacon thought acids rather than gases were responsible for the corrosion of pipes, and that soft water was the worst because usually more acid. He described his experience with

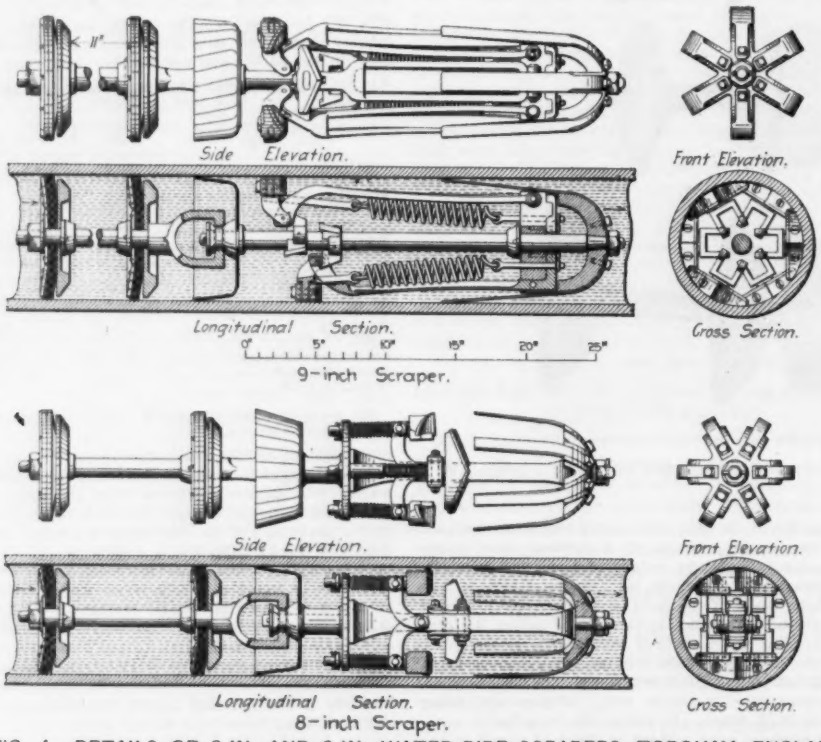


FIG. 4.—DETAILS OF 8-IN. AND 9-IN. WATER-PIPE SCRAPERS, TORQUAY, ENGLAND.

question of rusting is paramount, and water engineers should insist upon the pipes being free from scale and rust before dipping. The method usually adopted in this country is to heat the pipes in an open cylindrical stove of brickwork, at the bottom of which is a fire, and when the pipes have attained a heat of about 600° F. they are dipped in composition near boiling point. The pipes are left in this composition until they have acquired the temperature of the liquid, and are then taken out and allowed to cool whilst hanging. Any portion of the coating which is damaged while the pipes are being handled should be painted with a natural asphalt dissolved in bisulphate of carbon. The following process has been recommended for steel pipes. During rolling it is found that the surface of the steel is changed into a magnetic oxide (black oxide), which resists corrosion, but soon scales off. This scale should be removed by placing the pipes in a sulphuric acid bath, followed by one of lime water, immediately before the

peaty deposits, and the brush devised by him, shown in Fig. 5, as follows:

Nodules were not the only cause of a fall in the discharging capacity of a main. The so-called "peaty" deposit was also a source of trouble. This was not really peat, but was oxide of iron and manganese, and was common when upland water was passed through cast-iron pipes. Some two or three years back he had been consulted in regard to a reduction in the capacity of the upper Vyrnwy main from the lake to the Oswestry filter beds, a distance of 13 miles. The daily discharge had fallen from between 16,000,000 and 17,0000,000 (Imp.) gallons to between 12,000,000 and 13,000,000 gallons. A thorough examination showed that the retardation could not be acounted for by nodules, but this so-called peaty deposit was found in the scour-boxes. It was very heavy and very fine. Such a material on reaching an inverted syphon, of which there were many in the line of main, would tend to collect in the "rising" leg, and would increase the resistance to flow there, partly by producing eddies and partly by increasing the gravimetric density of the contents of this leg. The material had been investigated by Dr. Campbell Brown and Professor Boy[illegible], and whilst final conclusions had not yet been arrived [illegible] was shown that a bacterium was responsible for its production. As the Vyrnwy pipes had been very carefully coated, he did not like to have them scraped, but thought that possibly brushing them would prove effective. The brush used consisted of a shaft, on which was mounted a drum, nearly fitting the pipe, which served to drive the whole forward. Two other drums, each 2½ ins. less diameter than the pipe, were mounted on the same [illegible] and armed with bristles of whalebone, arranged [illegible] fashion, so that water flowing past tended to rotate the brushes. The water flowed at one mile an hour, and the brush moved forward at about one-third mile per hour. Between the brush and the pipe the water therefore flowed at a much greater speed, and the brushes were thus [illegible]

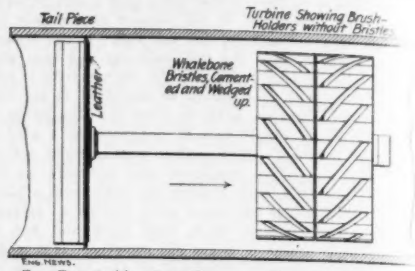


Fig. 5.—Brush Used to Remove Peaty Deposits from Water Pipes at Liverpool.

ficiently rotated one in one direction and the other in the other. When first put into the pipe it was feared that there would be a difficulty in following the brush as it made so little noise. This turned out to be the case, but it arrived quite safely at the scour-box 1½ miles away. The effect of its passage on the discharge was quite marked, although only 1½ miles out of a total of 13 had been passed through. A policeman's rattle was then attached the brush, which allowed of its progress being traced by the sound made, and with this arrangement the whole distance to Oswestry was traversed, with the result that the discharge was again brought up to between 16,000,000 and 17,000,000 (Imp.) gallons per day. With filtered water, this deposit was not produced, and therefore the mains leading from Oswestry maintained their original capacity. As to nodules, there was some reason to believe that these also were, in the first place, due to the action of bacteria. The author in his paper had mentioned that incrustation was less with filtered than with unfiltered water, and this Mr. Deacon could confirm. Filtration reduced the acidity of the water, and might even render it alkaline, and prevented almost entirely the production of the so-called peaty deposit.

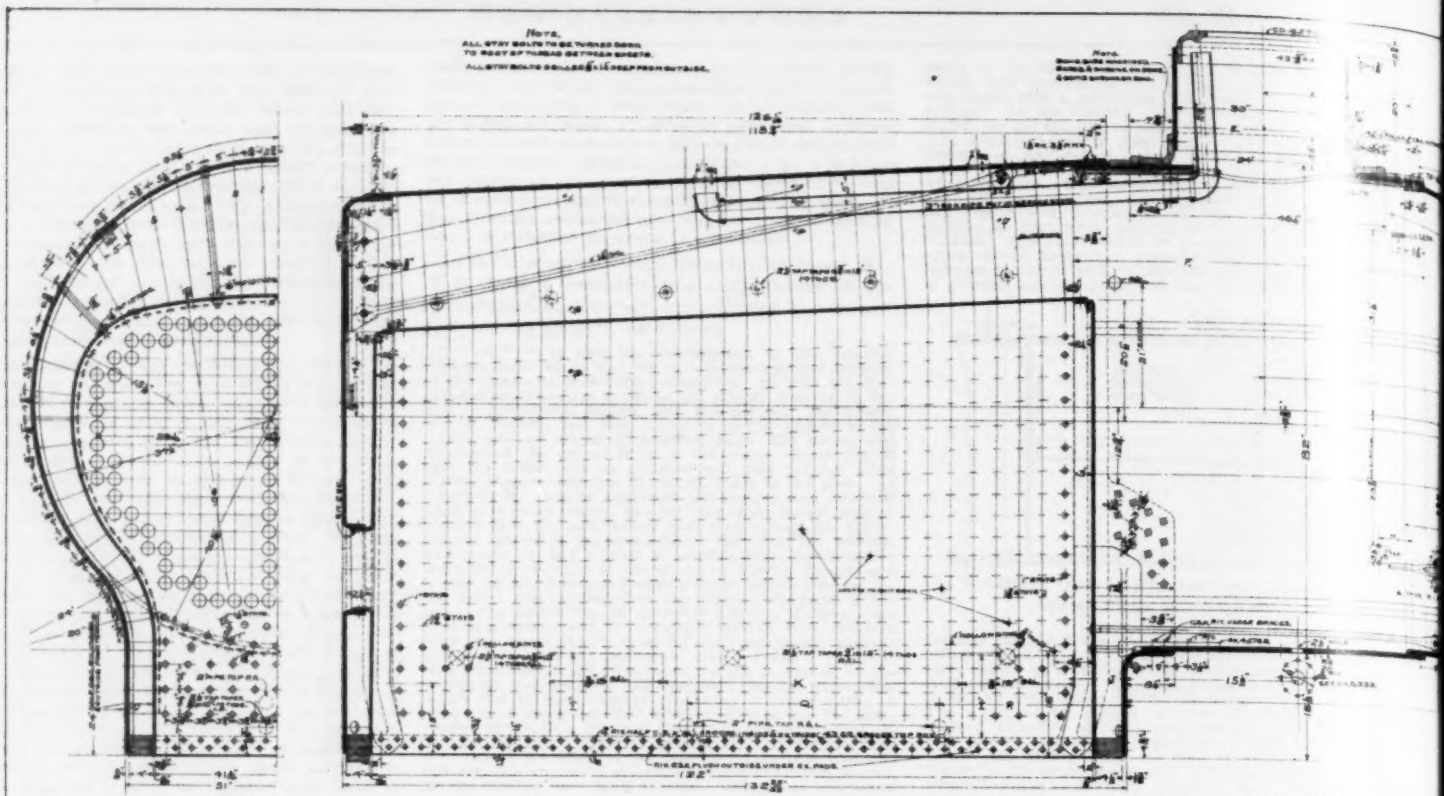
Further particulars regarding this brush are taken from "The Engineer" for Nov. 17, 1899, as follows:

The drawings show the turbine brush as originally designed and used; the tail piece, armed with three rings of leather, was necessary to hold the machine back. Without this or its equivalent there could be no rotation, and the advance of the brush being nearly as rapid as the flow of the water it would certainly jam with the accumulation of brushed deposit. The leathers, however, being the only comparatively unyielding portions in contact with the pipe, were exposed to every obstruction and moved rapidly. Before the work was half done the machine was reversed, the turbine brushes being placed in the rear, and the leathers being removed. Instead of these, strong steel springs, armed with blocks of beech, were set so as to break joint and support the shaft axially, and afford the necessary resistance to forward motion. This arrangement answered well.

The brown deposit referred to is common but not universal in soft-water pipes. It coats the interior like a shiny velvet, but in this condition does not offer much resistance to the flow of water. As, however, it becomes detached and falls to the bottom, the sliminess disappears, and there is little or no tendency of the particles to adhere. In this condition, by increasing the mean density and eddying of the fluid in the case cited, mainly in the 26 up-stream portions of the Vyrnwy main, without materially adding to the mean density in the 26 down-stream portions, it acted as a very serious drag, and was undoubtedly the main cause of reduced flow in this as in many other cases.

The experience of Mr. Edw. M. Eaton, as engineer of the water-works of Sheffield, was stated by him, in part, as follows:

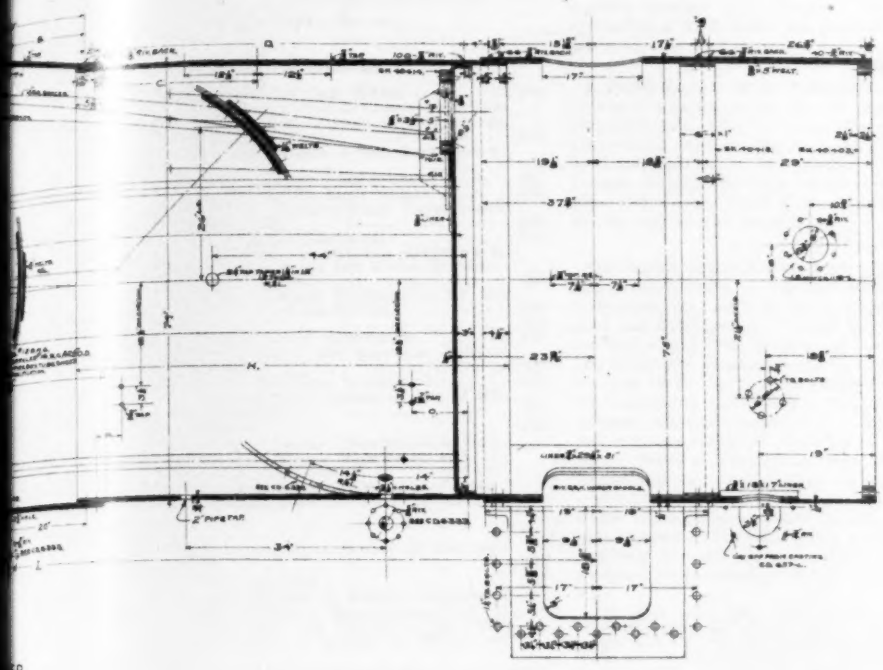
The water at Sheffield was from moorlands and very soft, and its corrosive effects were most remarkable. When he first went to Sheffield several miles of service pipes were nearly choked, the free diameter being reduced to the thickness of a tobacco pipe. To clean these 3-in. or 4-in. pipes he had adopted ordinary spring flue scrapers, mounted at the end of ¾-in. gas tubing. With this a gang of four men could clean 100 ft. of pipe each way in a single night, the cost for a 4-in. pipe being 20 cts. per yd. This method, had, however, to be abandoned in the residential districts of the town, as the loosened iron oxide and peaty matter caused constant complaints from consumers, but it was still used in the poorer districts. For larger mains up to 12 ins. in diameter he used a scraper of the Glenfield model, and found it very satisfactory, from ½ to ¾ mile of 9-in. to 10-in. main being cleaned and closed up again in a single night. As to the peaty deposit he could not follow Mr. Deacon, since at Sheffield the stuff was peat. A high-level main belonging to the system was coated with a black velvery deposit of the material, 90% of which analysis showed to be organic matter. When the pipes were scoured they got cartloads of it; nothing but peat! Nodules formed in the upper part of this main, and he was unable to agree with Mr. Deacon that they arose from a fracture in the coating, as he had examined hundreds of cases. In Sheffield, at any rate, the nodules seemed to be laid down from iron in solution, in support of which he would say that they occurred on the gun-metal valve at the bottom of the high-level main already referred to. Each tubercle, in fact, had a fragment of moss or peat as its center, surrounding which was a very friable layer of iron oxide, followed by layers of harder oxide.

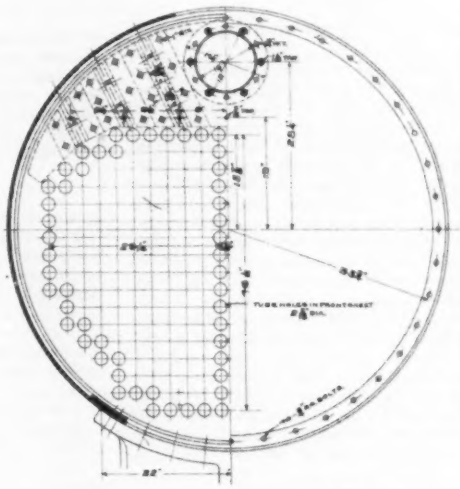


HALF CROSS-SECTION THROUGH FIRE-BOX.

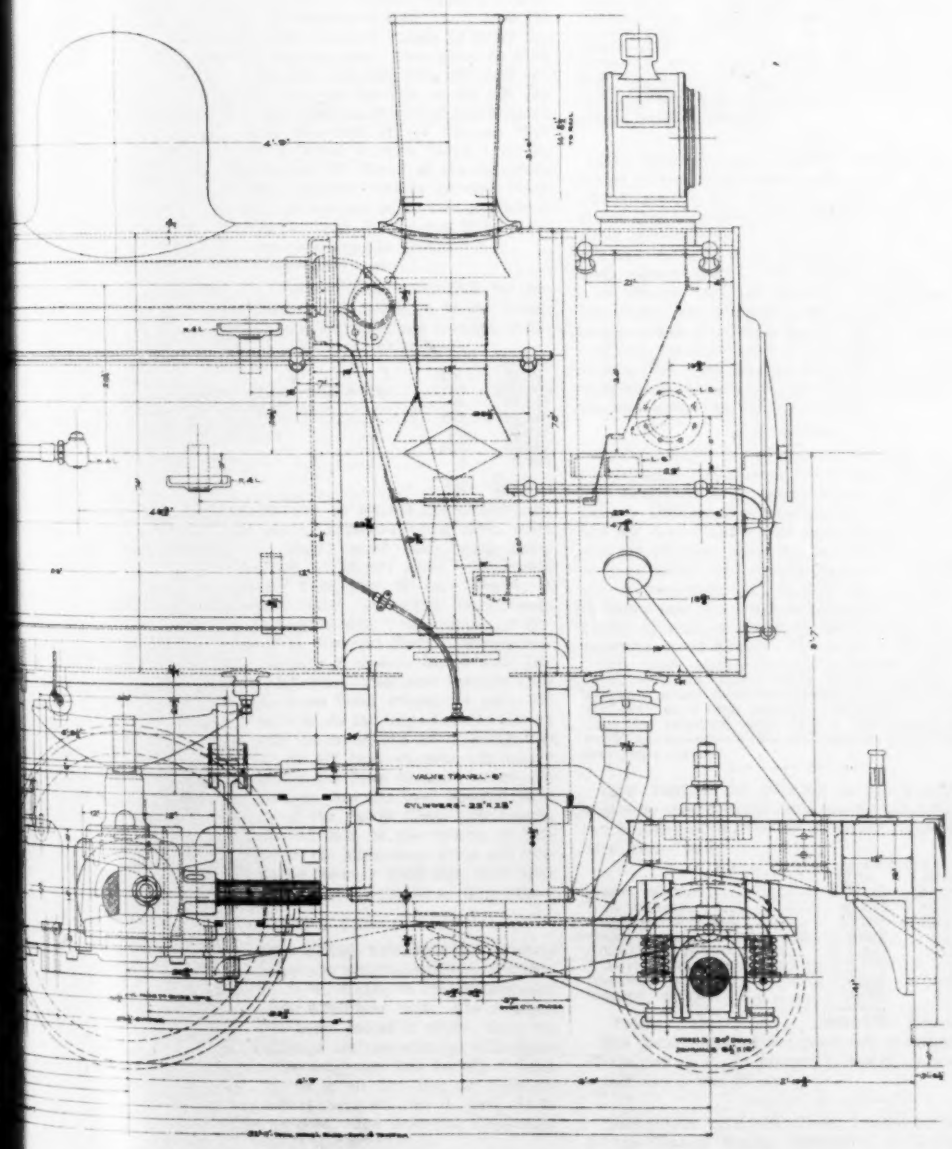
LONGITUDINAL SECTION

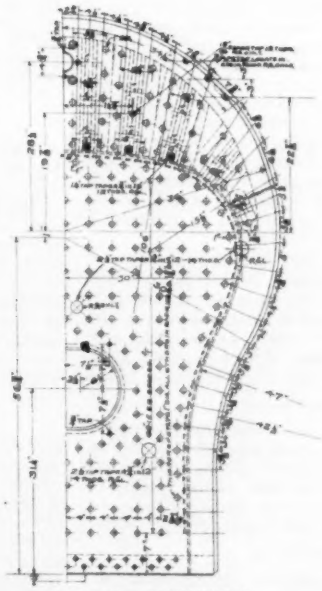
GENERAL ELEVATION.





HALF FRONT ELEVATION OF BOILER AND HALF SECTION THROUGH SMOKE-BOX.





HALF REAR ELEVATION OF BOILER.

CONSOLIDATION LOCOMOTIVE;

RIO GRANDE WESTERN RY.

John Hickey.

General Master Mechanic.

Richmond Locomotive and Machine Works,

Richmond, Va., Builders.

CHAS. HART, LITH., 98 VESEY ST., N. Y.